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OLD WEST REGIONAL COMMISSION

ANNUAL REPORT

June 25, 1974 to June 30, 1975  
Project Number 10470022

A Study to Evaluate Potential Physical, Biological, and Water Use Impacts  
of Water Withdrawals and Water Development on the Middle and Lower Portions  
of the Yellowstone River Drainage in Montana

# PLEASE RETURN

Submitted by

Gary J. Wicks, Director  
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and Conservation  
32 S. Ewing  
Helena, Montana 59601

To

Dr. Kenneth Blackburn  
Project Coordinator  
Old West Regional Commission  
Room 306A Fratt Building  
Billings, Montana 59102

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## INTRODUCTION

Contracts were entered with the Montana Department of Fish and Game (\$190,893) for performance of tasks 1, 2, 3, and 7; with the Water Quality Bureau of the Montana Department of Health and Environmental Sciences (\$90,955) for task 6; and with the University of Montana (\$10,000) for a portion of task 8. Project personnel were employed by each of the agencies, including the Department of Natural Resources and Conservation. Bob Anderson, Project Manager, began work on February 3, 1975.

Following is a description of the first year's progress, by task, with some preliminary results included. There are no discrepancies between the terms of the contract and the work performed.



TASK 1.     INVESTIGATION OF AQUATIC COMMUNITIES. This task entails particular attention to the habitats of the Tongue River Basin. The Grantee shall inventory and investigate the life history of aquatic invertebrates and forage fish which support major fish populations in the lower and middle Yellowstone.

## AQUATIC INVERTEBRATE STUDIES

In August, 1974, the study was initiated on the Yellowstone and Tongue rivers of southern Montana. Initial stages of this study are involved with an inventory of the aquatic macroinvertebrates of these two rivers under the direction of Bob Newell, Montana Department of Fish and Game. Later research will deal with an examination of life history phenomena, flow requirements, and autecology of the macroinvertebrates.

Twenty sampling stations established along the Yellowstone River (table 1) were sampled monthly except during severe ice conditions (January-March) and peak runoff months (May-June). Stations 1-4 were sampled by Rod Berg (Montana Department of Fish and Game), stations 5-11 were sampled by Dennis Schwehr (University of Montana), and the remainder of the river was sampled by Newell. When conditions permitted, samples were taken using Hester-Dendy multiple plate artificial substrate samplers (U.S. Environmental Protection Agency 1973) with a colonization period of 4 weeks. When the artificial substrates were not in use, kick samples of two-minute duration were taken.

Eight sampling stations were established along the Tongue River (table 2); kick samples were taken quarterly. These stations correspond to fish-collecting stations.

All organisms collected from the Yellowstone River were identified to genus and counted. The data were sent to the State Data Processing Bureau where several species-diversity indices were calculated. Invertebrates collected from the Tongue River were identified to genus but not counted.

Species-diversity indices were calculated using the following formulae:

- a. Shannon-Weaver function ( $\bar{d}$ ) =  $\sum_{i=1}^S (N_i/N) \log_2 (N_i/N)$
- b. Equitability ( $E_m$ ) =  $\bar{d}/d_{\max}$  (Margalef 1957, Krebs 1972)
- c. Redundancy ( $R$ ) =  $\frac{d_{\max} - \bar{d}}{d_{\max} - d_{\min}}$  (Wilhm and Dorris 1966, 1968)

- d. Theoretical maximum diversity ( $d_{\max}$ ) =  $(1/N) [\log_2 N! - S \log_2 (N/S)!]$
- e. Theoretical minimum diversity ( $d_{\min}$ ) =  $(1/N) \{ \log_2 N! - \log_2 [N-(S-1)]! \}$
- f. Evenness ( $J'$ ) =  $\bar{d} / \log_2 S$  (Pielou 1969, Egloff and Brakel 1973)
- g. Species richness (SR) =  $\bar{d} - \bar{d} / \log_2 N$  (Orr et al. 1973)

where: S = number of species

$N_i$  = number of individuals in the  $i^{\text{th}}$  species

$N$  = total number of individuals

A high (>3.0) Shannon-Weaver index generally means a healthy community, while a low index (<1.0) generally means the community is under some type of stress (Wilhm 1970a, 1970b, 1970c).

Equitability has been found to be very sensitive to even slight levels of degradation. Healthy communities have values of 0.0 to 0.3 (U.S. Environmental Protection Agency 1973).

Redundancy, a measure of the repetition of information within a community, expresses the dominance of one or more species and is inversely proportional to the wealth of species. Redundancy is maximal when no choice of species exists and minimal when there is a large choice of species.

Community distribution has maximum evenness if all the species abundances are equal; the greater the disparities among species abundances, the smaller the evenness.

Species richness is a little-used index that shows maximal values with large numbers of species.

Table 2 gives the distribution of macroinvertebrates in the Tongue River. At the genus level, the Ephemeroptera are the most diverse with 12 genera collected. No distinct distributional patterns were observed. Although no quantitative samples were taken, it was evident that the caddisfly Hydropsyche sp. and the Diptera family Chironomidae were the most abundant organisms collected. Two interesting species collected were Acroneuria abnormis, which has never been collected in Montana before this study, and the large freshwater mussel Lampsilis siliquoidea.

The invertebrate fauna of the Yellowstone River is considerably more diverse than that of the Tongue River. Several interesting patterns of longitudinal distribution occur in the 550 miles of Yellowstone River examined in this study. The Ephemeroptera (mayflies) exhibit some distinct patterns of distribution (table 3). The mayfly community is composed of several species confined to the upper river, several species found only in the lower river, and 4 species found throughout the river. Individuals of the genera Baetis, Ephemerella and Rhithrogena were the most numerous. The Ephemeroptera comprised a mean of 44 percent of the fauna, and percent composition ranged from 11 to 88 percent (table 9).

TABLE 1. Yellowstone River sampling stations.

No.	Location	County	Elevation	River Mile *
1	Corwin Springs	Park	5110 ft.	549
2	Mallard Rest Access	"	4620	515
3	above Livingston	"	4490	501
4	above Shields River	"	4380	497
5	Grey Bear access	Sweetgrass	4100	468
6	below Greycliff	"	3880	444
7	Columbus	Stillwater	3566	411
8	Laurel	Yellowstone	3294	391
9	Duck Creek Bridge	"	3140	360
10	Huntley	"	3110	349
11	Custer	"	2720	300
12	Bighorn River	Treasure	2700	296
13	Myers	"	2640	279
14	Forsyth	Rosebud	2490	234
15	Miles City	Custer	2335	184
16	Terry	Prairie	2190	138
17	Glendive	Dawson	2045	93
18	Intake	"	1998	71
19	Sidney	Richland	1892	30
20	Cartwright, N.D.	McKenzie	1850	9

---

\* Mouth of the Yellowstone River is river mile 0.

TABLE 2. Macroinvertebrate fauna of the Tongue River, Montana

Taxa	Sta. no.	8	7	6	5	4	3	2	1
		Dam Section	Hosford	Birney	Ashland	Viall	S - H	Orcutt	Keogh
Ephemeroptera									
<u>Baetis</u> spp.		X	X	X		X	X		
<u>Baetisca</u> sp.							X		
<u>Brachycercus</u> sp.						X			
<u>Choroterpes</u> sp.					X		X		
<u>Dactylobaetis</u> sp.							X		
<u>Ephemerella</u> sp.		X	X	X	X	X	X	X	
<u>Heptagenia</u> sp.				X	X	X	X	X	
<u>Leptophlebia</u> sp.				X	X			X	
<u>Rhithrogena</u> sp.				X	X	X	X	X	X
<u>Stenonema</u> sp.			X				X		
<u>Traverella</u> sp.				X	X	X	X	X	
<u>Tricorythodes</u> sp.		X	X	X	X	X	X	X	
Trichoptera									
<u>Brachycentrus</u> sp.		X		X	X	X	X	X	X
<u>Cheumatopsyche</u> sp.		X	X	X	X	X	X	X	X
<u>Glossosoma</u> sp.			X	X					
<u>Hydropsyche</u> sp.		X	X	X	X	X	X	X	X
<u>Hydroptila</u> sp.		X	X	X				X	X
<u>Mystacides</u> sp.				X	X			X	
<u>Oecetis</u> sp.				X	X		X	X	
Plecoptera									
<u>Acroneuria</u> sp.				X			X	X	X
<u>Brachyptera</u> sp.				X		X	X	X	X
<u>Isogenus</u> sp.				X	X	X	X	X	X
Coleoptera									
<u>Dubiraphia</u> sp.			X	X					
<u>Microcylloepus</u> sp.			X	X	X				
<u>Stenelmis</u> sp.			X	X	X	X	X	X	X



TABLE 2 (Continued)

	Sta. no.	8	7	6	5	4	3	2	1
Taxa		Dam Section	Hosford	Birney	Ashland	Viall	S - H	Orcutt	Keogh
Mollusca									
<u>Ferrissia</u> sp.		X	X	X					
<u>Gyraulus</u> sp.			X						
<u>Lymnaea</u> sp.		X	X						
<u>Lampsilis</u> sp.									X
<u>Physa</u> sp.		X	X	X					
<u>Pisidium</u> sp.			X				X		
<u>Sphaerium</u> sp.			X						
Odonata									
<u>Argia</u> sp.			X					X	
<u>Calopteryx</u> sp.			X			X	X		
<u>Enallagma</u> sp.									
<u>Ischnura</u> sp.			X						
<u>Gomphus</u> sp.				X					
<u>Ophiogomphus</u> sp.		X	X	X	X	X	X		
Lepidoptera									
<u>Cytaclista</u> sp.		X	X				X	X	
Turbellaria									
<u>Dugesia</u> sp.		X	X	X	X		X	X	
Hemiptera									
Corixidae		X	X	X				X	X
<u>Rhagovelia</u> sp.					X				
Diptera									
Chironomidae		X	X	X	X	X	X	X	X
<u>Cardiocladius</u> sp.		X		X					
<u>Diamesa</u> sp.		X		X					
<u>Eukiefferiella</u> sp.				X					X
<u>Orthocladius</u> sp.		X					X		
<u>Rheotanytarsus</u> sp.				X					
Simuliidae									
<u>Simulium</u> sp.		X	X	X	X	X	X	X	
Tipulidae									
<u>Hexatoma</u> sp.				X	X		X	X	X
Oligochaeta			X	X					

TABLE 3. Longitudinal distribution of Ephemeroptera of the Yellowstone River

TAXA	STATIONS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<u>Baetis</u> ( <u>propinquus</u> )?	x																			
<u>Ephemerella</u> <u>hecuba</u> ...		x																		
<u>E.</u> <u>heterocaudata</u> .....		x																		
<u>E.</u> <u>hystrix</u> .....		x	x																	
<u>Epeorus</u> <u>albertae</u> .....		x																		
" <u>longimanus</u> ...		x	x																	
<u>Ephemerella</u> <u>doddsi</u> ...		x	x	x	x	x	x													
" <u>tibialis</u> ..		x	x	x	x															
" <u>grandis</u> ..		x	x	x	x	x	x													
<u>Paraleptophlebia</u>																				
<u>heteronea</u> ....		x	x	x	x	x	x	x												
<u>Ameletus</u> ( <u>oregonensis</u> )?	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
<u>Ephemerella</u> <u>margarita</u>		x	x	x	x	x	x													
" <u>inermis</u> ..		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
<u>Baetis</u> ( <u>alexanderi</u> )?.		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
" <u>parvus</u> .....		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Heptagenia</u> <u>elegantula</u>		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Rhithrogena</u> <u>hageni</u> ...		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Tricorythodes</u> <u>minutus</u>					x	x	x	x	x	x	x	x	x	x						
<u>Leptophlebia</u>																				
( <u>gravastella</u> )? .			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
<u>Traverella</u> <u>albertana</u> .							x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Stenonema</u> sp.									x	x	x	x	x	x	x	x	x	x		
<u>Choroterpes</u>																				
( <u>albiannulata</u> )?									x	x	x	x	x	x	x	x	x	x		
<u>Baetisca</u> sp.															x					
<u>Dactylobaetis</u> ( <u>cepheus</u> )?																	x	x	x	x
<u>Ephoron</u> <u>album</u> .....																	x	x	x	x
<u>Lachlania</u> <u>powelli</u> ....																		x		
<u>Ametropus</u> ( <u>neavei</u> )?..																				x
<u>Brachycercus</u> ( <u>prudens</u> )?																				x
<u>Isonychia</u>																				
( <u>sicca campestris</u> )?																				x

The Trichoptera (caddisflies) decrease in diversity downstream (table 4). The majority of the fauna is confined to the upper 9 stations. The genera Cheumatopsyche and Hydropsyche were the most abundant caddisflies collected and also the most widespread. Trichoptera comprised an average of 16 percent of the fauna, and percent composition ranged from 0 to 58 percent (table 9). Approximately 20 percent of the species have been identified.

The Plecoptera (stoneflies) decrease in diversity in a downstream direction (table 5). A total of 29 species representing 14 genera were collected. Most of the species (25) were found in the upper river; only 4 species were confined to the lower 10 sampling stations, including several species not previously known east of the continental divide: Brachyptera pacifica, B. fosketti, Isogenus frontalis colubrinus and Acroneuria abnormis. Stoneflies comprised a mean of 6 percent (range 0 to 15 percent) of the fauna (table 9). About 95 percent of the species have been identified.

The Diptera of the Yellowstone are dominated by the family Chironomidae (midges); 19 genera have been tentatively identified (table 6). The Diptera comprised a mean of 33 percent of the total fauna (range 4 to 78 percent) (table 9).

The miscellaneous orders found in the river (table 7) comprised a minor portion of the invertebrate fauna (mean of 1 percent, range 0 to 11 percent -- table 9). Very few species have been identified.

A checklist of the fauna of the Yellowstone and Tongue rivers is presented in table 8. An attempt was made to identify as many species as possible. In some cases, adults were collected and positive identification was possible. In other cases, the most probable species for a particular genus was tentatively placed on the list in parentheses with a question mark following.

Species diversity values are presented in table 10. Only 5 months of data have been analyzed to date, but it appears that none of the sampling stations are under any excessive environmental stress. Shannon-Weaver index ( $\bar{d}$ ) values range from 1.53 to 3.84. No distinct patterns of indices are evident throughout the river system. Further interpretation with the limited number of samples is not warranted at this time.

Prior to initiation of the present study, several quantitative bottom samples were taken by Fish and Game personnel using a Waters round square-foot sampler (Waters and Knapp 1961). The data gathered from these samples are presented in tables 11-13. The stations listed in these tables correspond to station sites in table 1. In table 11 station 4a is above and 4b below the Shields River. These data permit limited evaluation of the quantitative nature of the benthos of the Yellowstone River at the genus and order levels. During the taking of these samples, representatives of the miscellaneous orders were accidentally discarded; totals presented in tables 11-13 lack these values.

TABLE 4. Longitudinal distribution of Trichoptera of the Yellowstone River

TAXA	STATIONS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<u>Amiocentrus aspilus</u> ..		x																		
<u>Rhyacophila</u> sp.....	x	x	x	x	x															
<u>Glossosoma</u> sp.....	x	x	x	x	x	x	x	x	x											
<u>Glossosoma velona</u> ....								x												
<u>Psychomyia</u> sp.....	x	x	x	x	x	x	x	x												
<u>Athripeodes</u> sp.....	x	x	x	x	x	x	x	x	x											
<u>Lepidostoma</u> sp.....	x	x	x	x	x	x	x	x	x	x										
<u>Arctopsyche grandis</u> ...	x	x	x	x	x	x	x	x	x	x										
<u>Brachycentrus</u> sp.....	x	x	x	x	x	x	x	x	x	x										
<u>Oecetis</u> sp.....							x		x											
<u>Oecetis disjuncta</u> .....												x								
<u>Hydroptila</u> sp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
<u>Cheumatopsyche</u> sp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Cheumatopsyche enonis</u> .										x	x	x	x	x	x					
<u>Hydropsyche</u> sp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>H. occidentalis</u> .....	x											x								
<u>H. separata</u> .....																		x		
<u>Polycentropus</u> sp.....												x								
<u>Ochrotrichia potomac</u> ..												x								
<u>Leptocella</u> sp.....												x					x	x		
<u>Neotrichia</u> sp.....																	x			

TABLE 5. Longitudinal distribution of Plecoptera of the Yellowstone River

TAXA	STATIONS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<u>Paraleuctra sara</u> .....	x																			
<u>Pteronarcys</u>																				
<u>californica</u> .....	x	x	x	x	x															
<u>Arcynopteryx parallela</u>	x	x	x	x	x	x	x	x												
<u>Hesperoperla pacifica</u> ..	x	x	x	x	x	x	x	x												
<u>Isocapnia missouri</u> ....		x	x	x	x	x	x	x												
" <u>vedderensis</u> ....		x	x	x	x	x	x													
<u>Nemoura besametsa</u> .....	x	x																		
" <u>cinctipes</u> .....		x	x	x	x	x	x	x	x											
<u>Claassenia sabulosa</u> ...		x	x	x	x	x	x	x	x											
<u>Pteronarcella badia</u> ...	x	x	x	x	x	x	x	x	x	x										
<u>Alloperla</u> spp.....	x	x	x	x	x	x	x	x	x	x	x	x								
" <u>signata</u> .....		x	x	x	x	x														
" <u>pallidula</u> ....		x	x	x	x	x	x	x	x											
" <u>coloradensis</u>							x													
<u>Capnia</u> spp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
" <u>distincta</u> .....		x																		
" <u>confusa</u> .....		x	x	x	x	x														
" <u>gracilaria</u> ....		x	x																	
" <u>poda</u> .....		x	x	x	x	x														
" <u>limata</u> .....								x	x	x	x	x	x	x	x					
<u>Brachyptera</u> spp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
<u>B. nigripennis</u> .....		x	x	x	x	x	x	x												
<u>B. pacifica</u> .....												x	x							
<u>B. fosketti</u> .....																x	x	x	x	
<u>Isoperla</u> spp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
" <u>patricia</u> .....		x	x	x	x	x	x	x												
" <u>mormona</u> .....		x	x	x	x	x	x													
" <u>longiseta</u> ....							x													
<u>Isogenus</u> spp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
" <u>aestivalis</u> ...		x																		
" <u>tostonus</u> ....		x	x	x	x	x	x	x												
" <u>elongatus</u> ....		x	x	x	x	x	x													
" <u>frontalis</u> ....																x	x	x	x	
<u>Acroneuria abnormis</u> ...																x				

TABLE 6. Longitudinal distribution of Diptera of the Yellowstone River

TAXA	STATIONS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<b>BLEPHAROCERIDAE</b>																				
<u>Agathon</u> sp.....		x																		
<b>CERATOPOGONIDAE</b>																				
												x	x				x			
<b>CHIRONOMIDAE</b>																				
<u>Orthocladius</u> sp....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Cardiocladius</u> sp...	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
<u>Diamesa</u> sp.....	x	x	x	x	x	x	x	x												
<u>Metriocnemus</u> sp....		x																		
<u>Procladius</u> sp.....			x																	
<u>Pseudodiamesa</u> sp...							x	x												
<u>Chironomus</u> sp.....								x												
<u>Cricotopus</u> sp.....									x											
<u>Ablabesmyia</u> sp.....		x		x							x	x						x	x	
<u>Microtendipes</u> sp...		x	x				x	x	x		x	x								
<u>Rheotanytarsus</u> sp..	x							x			x				x					
<u>Eukiefferiella</u> sp..	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x		
<u>Brillia</u> sp.....						x				x	x	x							x	
<u>Tribelos</u> sp.....				x				x	x					x						
<u>Clinotanypus</u> sp....												x							x	
<u>Cryptochironomus</u> sp.															x					
<u>Cryptocladius</u> sp....														x					x	
<u>Paralauterborniella</u>							x										x	x		
<u>Trichocladius</u> sp....																		x		
<b>EMPIDIDAE</b>																				
<u>Hezerodromia</u> sp.....		x	x	x	x			x			x									
<b>RHAGIONIDAE</b>																				
<u>Atherix variegata</u> ...		x	x	x	x	x	x	x	x	x	x									
<b>SIMULIIDAE</b>																				
<u>Simulium</u> sp.....		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<b>TANYDERIDAE</b>																				
<u>Protoplasa fitchii</u> ..					x															
<b>TIPULIDAE</b>																				
<u>Dicranota</u> sp.....														x			x			
<u>Hexatoma</u> sp.....		x	x	x	x	x	x	x	x	x	x	x	x	x	x					
<u>Holorusia</u> sp.....				x																
<u>Tipula</u> sp.....									x											

TABLE 7. Distribution of the miscellaneous orders of the Yellowstone River

TAXA	STATIONS																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ISOPODA																				
<u>Asellus racovitzai</u> ..										x										
LEPIDOPTERA																				
<u>Cataclysta</u> sp.....						x								x						
HEMIPTERA																				
<u>Ambrysis mormon</u> .....												x								
<u>Hesperocorixa</u> sp....								x	x	x	x	x	x	x						x
OLIGOCHAETA.....																				
												x	x	x			x	x		
MOLLUSCA																				
<u>Ferrissia</u> sp.....																	x	x		
<u>Gyraulus</u> sp.....																				x
<u>Physa</u> sp.....							x			x										
ODONATA																				
<u>Gomphus</u> sp.....																				x
<u>Amphiagrion</u> .sp.....									x											
COLEOPTERA																				
<u>Hydroporus</u> sp.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x		
<u>Gyrinus</u> sp.....							x													
<u>Microcylloepus</u> sp...					x	x	x	x												
<u>Dubiraphia</u> sp.....																x				
<u>Stenelmis</u> sp.....																x		x		
<u>Optioservus</u> sp.....	x				x	x	x	x				x								
<u>Zaitzevia</u> sp.....					x															
ACARI.....	x	x	x	x																

TABLE 8. Checklist of the aquatic macroinvertebrates of the Tongue and Yellowstone rivers

Phylum Arthropoda

Order Ephemeroptera

Family Siphonuridae

Ameletus (oregonensis McD.) ?

Isorychnia (sicca campestris McD.) ?

Family Baetidae

Baetis (alexanderi M.S. Edmunds and Jensen, sp.nov.) ?

" (parvus Dodds

" (propinquus Walsh) ?

Dactylobaetis (cephus Traver & Edmunds) ?

Family Oligoneuridae

Lachlania (powelli Edmunds) ?

Family Heptageniidae

Epeorus (Iron) albertae (McD.)

" (") longimanus (Eaton)

Heptagenia elegantula (Eaton)

Rhithrogena hageni Eaton

Stenonema sp.A

Family Ametropodidae

Ametropus (neavei McD.) ?

Family Leptophlebiidae

Choroterpes (albiannulata McD.) ?

Leptophlebia (gravastella Eaton) ?

Paraleptophlebia heteronea (McD.)

Traverella albertana (McD.)

Family Ephemerellidae

Ephemerella (Attenuatella) margarita Needham

" (Caudatella) heterocaudata heterocaudata McD.

" (") hystrix Traver

" (Drunella) doddsi Needham

" (") grandis grandis Eaton

" (Ephemerella) inermis Eaton

" (Serratella) tibialis McD.

" (Timpanoga) hecuba hecuba (Eaton)

Family Tricorythidae

Tricorythodes minutus Traver

Family Polymitarcidae

Ephoron album (Say)

Family Caenidae

Brachycercus (prudens McD.) ?

Family Baetiidae

Baetisca sp.A

Order Trichoptera

Family Rhyacophilidae

Rhyacophila sp.A



TABLE 8 (Continued)

## Family Glossosomatidae

Glossosoma sp.A  
       " velona Ross

## Family Psychomyiidae

Polycentropus sp.A  
Psychomyia sp.A

## Family Hydropsychidae

Arctopsyche grandis (Banks)  
Cheumatopsyche sp.A  
       " enonis Ross  
Hydropsyche sp.A  
       " occidentalis Banks  
       " separata Banks

## Family Hydroptilidae

Hydroptila sp.A  
Ochrotrichia potomae Denning  
Neotrichia sp.A

## Family Leptoceridae

Athripsodes sp.A  
Leptocella sp.A  
Oecetis sp.A  
Oecetis disjuncta (Banks)

## Family Lepidostomatidae

Lepidostoma sp.A

## Family Brachycentridae

Amiocentrus aspilus (Ross)  
Brachycentrus sp.A

## Order Plecoptera

## Family Nemouridae

Nemoura (Prostoia) hesanetsa Ricker  
       " (Zapada) cinctipes Banks  
Paraleuctra sara Claassen  
Capnia (Capnia) confusa Claassen  
       " (      "      ) gracilaria "  
       " (      "      ) linata Frison  
       " (Utacapnia) distincta Frison  
       " (      "      ) poda Hebecker & Gaufin  
Isocapnia missouri Ricker  
       " vederensis (Ricker)  
Brachyptera (Taenionema) fochetti Ricker  
       " (      "      ) nigrinervis (Banks)  
       " (      "      ) pacifica (Banks)

## Family Pteronarcidae

Pteronarcella badia (Hagen)  
Pteronarcys californica Newport

## Family Perlodidae

Arcynopteryx (Skwala) parallela (Frison)  
Isogenus (Cultus) aestivalis (Needham & Claassen)  
       " (      "      ) torrens Ricker  
       " (Isogenoides) frontalis colubrimus Hagen

TABLE 8 (Continued)

Isoperla mormona Banks  
" longiseta Banks  
" patricia Frison  
 Family Chloroperlidae  
Alloperla (Suwallia) pallidula (Banks)  
" (Sweltsa) coloradensis (Banks)  
" (Triznaka) signata (Banks)  
 Family Perlidae  
Acroneuria abnormis Newm.  
" (Hesperoperla) pacifica Banks  
Claassenia sabulosa (Banks)

Order Isopoda

Family Asellidae

Asellus racovitzai racovitzai Williams

Order Lepidoptera

Family Pyralidae

Cataclysta sp.A

Order Hemiptera

Family Corixidae

Hesperocorixa sp.A

Family Naucoridae

Ambrysis mormon Mont.

Family Veliidae

Rhagovelia sp.A

Order Odonata

Family Gomphidae

Gomphus sp.A

Ophiogomphus sp.A

Family Agrionidae

Calopteryx sp.A

Family Coenagrionidae

Argia sp.A

Amphiagrion sp.A

Enallagma sp.A

Ichnura sp.A

Order Coleoptera

Family Dytiscidae

Hydroporus sp.A

Family Elmidae

Dubiraphia sp.A

Microcylloepus pusillus (LeConte)

Optioservus quadrimaculatus (Horn)

Stenelmis sp.A

Zaitzevia parrula (Horn)

Family Gyrinidae

Gyrinus sp.A

TABLE 8 (Continued)

Order Diptera

Family Blepharoceridae

Agathon sp.A

Family Ceratopogonidae

Family Chironomidae

Subfamily Tanypodinae

Ablabesmyia sp.A

Clinotanypus sp.A

Cryptocladius sp.A

Procladius sp.A

Subfamily Chironominae

Chironomus sp.A

Cryptochironomus sp.A

Microtendipes sp.A

Paralauterborniella sp.A

Rheotanytarsus sp.A

Subfamily Diamesinae

Diamesa sp.A

Pseudodiamesa sp.A

Subfamily Orthocladiinae

Brillia sp.A

Cardiocladius sp.A

Cricotopus sp.A

Eukiefferiella sp.A

Metriocnemus sp.A

Orthocladius sp.A

Trichocladius sp.A

Family Empididae

Hemerodromia sp.A

Family Rhagionidae

Atherix variegata Walker

Family Simuliidae

Simulium sp.A

Family Tanyderidae

Protoplasa fitchii O.S.

Family Tipulidae

Dicranota sp.A

Hexatoma sp.A

Holorusia sp.A

Tipula sp.A

Order Acari

Suborder Prostignata

Phylum Platyhelminthes

Class Turbellaria

Family Planariidae

Dugesia sp.A

TABLE 8 (Continued)

Phylum Annelida  
Class Oligochaeta

Phylum Mollusca

Order Basommatophora

Family Lymnaeidae

Lymnaea sp.A

Family Physidae

Physa sp.A

Family Planorbidae

Gyraulus sp.A

Family Ancyliidae

Ferrissia sp.A

Order Eulamellibranchia

Family Unionidae

Lampsilis siliquoidea (Barnes)

Order Heterodonta

Family Sphaeriidae

Pisidium sp.A

Sphaerium sp.A



TABLE 10. Species diversity indices

Sta.	d (Max.)	Max.Theoretical Diversity		Min.Theoretical Diversity		Redundancy		Evenness		Equitability		Richness	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	2.39	3.82	4.82	0.19	0.42	0.15	0.55	0.48	0.85	0.21	0.36	1.65	2.84
2	3.11	3.22	4.33	0.11	0.54	0.25	0.35	0.66	0.81	0.26	0.39	2.17	2.74
3	2.70	3.24	3.89	0.08	0.42	0.19	0.45	0.56	0.81	0.20	0.37	1.96	2.33
4	2.72	3.52	3.67	0.16	0.61	0.24	0.47	0.57	0.76	0.26	0.33	1.82	2.43
5	3.19	3.37	4.56	0.25	0.49	0.19	0.32	0.69	0.85	0.32	0.40	2.42	2.84
6	2.97	3.61	4.48	0.22	0.50	0.36	0.44	0.57	0.69	0.27	0.34	2.09	2.66
7	3.60	3.29	4.72	0.39	0.73	0.23	0.29	0.75	0.76	0.36	0.43	2.28	3.19
8	3.84	2.85	4.28	0.78	0.98	0.12	0.24	0.79	0.87	0.43	0.53	1.94	3.34
9	3.12	3.58	4.55	0.42	0.84	0.35	0.40	0.66	0.70	0.33	0.39	2.10	2.76
10	3.20	2.83	4.25	0.17	1.13	0.13	0.82	0.22	0.82	0.09	0.51	0.77	2.69
11	2.21	3.74	4.47	0.18	0.53	0.45	0.62	0.41	0.60	0.18	0.28	1.64	1.95
12	2.74	3.13	4.12	0.30	1.00	0.33	0.36	0.66	0.70	0.30	0.42	2.01	2.43
13	1.53		4.44		0.13	0.67		0.34		0.14		1.39	
14	2.94		4.17		0.63	0.35		0.67		0.37		2.57	
15	1.75		4.01		0.28	0.60		0.44		0.20		1.56	
16	-		-		-	-		-		-		-	
17	1.90		2.82		0.39	0.38		0.68		0.28		1.62	
18	2.84		3.91		0.73	0.34		0.69		0.39		2.45	
19	2.41		2.97		0.66	0.24		0.76		0.39		2.02	
20	3.36		3.96		1.04	0.21		0.84		0.51		2.84	

TABLE 11. Quantitative samples from the Yellowstone River,  
December 1973 (numbers are mean of 3 sq. feet)

	STATIONS					
	2	3	4a	4b	5	6
Ephemeroptera.....	315	863	457	653	188	249
Trichoptera.....	1045	1404	1224	1010	687	1430
Plecoptera.....	183	105	120	111	135	71
Diptera.....	550	784	247	517	69	49
Lepidoptera.....	0	0	0	0	0	2
TOTALS=	2093	3156	2048	2291	1079	1801

TABLE 12. Quantitative samples from the Yellowstone River, April 1974 (number/ft<sup>2</sup> and relative percentage)

Taxa	Below Armells Creek		Above Armells Creek		Miles City		Hysham	
	Number/ ft <sup>2</sup>	Relative Percentage	Number/ ft <sup>2</sup>	Relative Percentage	Number/ ft <sup>2</sup>	Relative Percentage	Number/ ft <sup>2</sup>	Relative Percentage
EPHEMEROPTERA	380		332		541		285	
<u>Baetis</u> sp.		15		40		49		54
<u>Ephemerella</u> spp.		0		0		1		1
<u>Rhithrogena</u> sp.		85		60		50		45
TRICHOPTERA	5		8		78		0	
<u>Cheumatopsyche</u> spp.		20		75		25		0
<u>Hydropsyche</u> spp.		80		25		75		0
PLECOPTERA	21		31		90		26	
<u>Isogenus</u> spp.		0		0		2		0
<u>Isoperla</u> spp.		100		100		98		100
DIPTERA	12		22		352		22	
<u>Chironomidae</u>		50		91		100		100
<u>Hexatoma</u> sp.		50		9		0		0
HEMIPTERA	0		0		7		0	
<u>Hesperocorixa</u> sp.						100		
Total Number	418		393		1068		333	



TABLE 13. Quantitative samples from the Yellowstone River, April 4, 1974 (number/ft<sup>2</sup> and relative percentage)

Taxa	Sampling Station							
	1	2	3	4a	4b	5	6	7
Relative Percentage								
EPHEMEROPTERA								
Baetis spp.	30	25	20	13	29	48	40	50
Epeorus spp.	1	-	-	-	-	-	-	-
Ephemerella spp.	62	51	61	86	71	51	40	50
Rhithrogena sp.	7	24	19	1	-	1	20	-
TRICHOPTERA								
Arctopsyche sp.	-	-	1	2	1	5	1	5
Athripsodes sp.	-	-	-	-	1	-	-	1
Brachycentrus sp.	-	4	5	8	40	30	20	15
Cheumatopsyche sp.	10	5	30	25	10	10	8	10
Glossosoma sp.	1	1	-	1	1	2	-	-
Hydropsyche sp.	60	60	60	60	40	30	50	50
Hydroptila sp.	0	-	-	-	-	-	1	15
Lepidostoma sp.	25	30	3	15	5	20	20	3
Psychomyia sp.	2	-	1	-	1	-	-	1
Rhyacophila sp.	2	-	-	-	1	3	-	-
PLECOPTERA								
Acroneuria sp.	20	-	-	-	-	-	-	-
Alloperla sp.	10	60	45	9	60	40	20	10
Brachyptera sp.	-	1	-	-	5	-	-	-
Claassenia sp.	-	-	-	-	-	10	-	-
Isogenus sp.	10	-	6	50	-	10	35	60
Isoperla sp.	10	38	45	40	-	5	20	10
Pteronarcella sp.	-	-	2	1	35	30	25	20
Pteronarcys sp.	50	1	2	-	-	5	-	-

TABLE 13 (Continued)

Taxa	Sampling Station							
	1	2	3	4a	4b	5	6	7
Relative Percentage								
DIPTERA								
<u>Atherix variegata</u>	3	1	5	1	5	5	1	-
<u>Chironomidae</u>	95	98	80	98	80	90	98	100
<u>Hemerodromia sp.</u>	-	-	-	1	-	-	-	-
<u>Hexatoma sp.</u>	1	-	5	-	9	5	1	-
<u>Protoplasia fitchii</u>	-	-	-	-	1	-	-	-
<u>Simulium sp.</u>	1	1	10	-	5	-	-	-
Number/ft <sup>2</sup> *								
EPHEMEROPTERA	256	126	278	167	406	342	181	70
TRICHOPTERA	414	93	169	437	716	495	129	328
PLECOPTERA	68	129	92	91	41	251	84	23
DIPTERA	494	532	371	444	344	171	190	349
Total	1232	900	910	1139	1507	1259	584	770

\* These numbers are a mean taken from three square-foot samples.

## FORAGE FISH INVESTIGATIONS

Maintenance of the piscivorous sport and nonsport fish populations of the lower Yellowstone depends on an adequate population of forage fish--any fish that is utilized as a source of food by other fish.

Most members of the Cyprinidae (minnow) family found in the lower Yellowstone are probably used as forage to some extent. Other species, such as the stonecat, are commonly found in fish stomachs. In addition, age 0 fish of both sport and nonsport fish species may be used as forage by adult fish. The objectives of the forage fish investigations are to: 1) collect and identify those fish species which may be utilized as a food source by other fish, and 2) identify the habitat requirements of important forage fish species. A food habits study currently being initiated with Bureau of Reclamation funding will identify those forage fish species important to the major sport and nonsport fish populations.

Forage fish samples were taken in the vicinities of Forsyth, Miles City, and Glendive during the fall of 1974. The initial objectives of this sampling were to obtain a reference collection of forage fish species, determine their distribution, and develop effective sampling techniques for forage species. Any attempt to determine relative abundance of forage fish species between areas depends on development of a standard unit of capture effort. If a standard unit of capture effort can be developed, then forage fish sampling sites will be established and sampled on a regular basis.

Several sampling techniques were tested during this report period for the capture of forage fish species and age 0 sport fish species. A 100-foot, 1/4-inch mesh, 8-foot deep seine is most effective in backwater areas for most forage and age 0 sport species. Certain species, such as the stonecat, are found in areas unsuitable for seining. In these cases, electrofishing with a mobile electrode and half-pulsed DC current will be used.

The 100-foot, 1/4-inch mesh seine will be used in those areas of the main channel which are suitable for seining. In areas of the main channel too deep or swift for seining, electrofishing with the boom electrode and DC current will be used.

Forage fish samples have not been sorted and identified. Analyses of samples will be done during high water and included in the next quarterly report.

## TONGUE RIVER FISH STUDIES

Fish populations in Montana have received far less attention in warm-water streams than in cold-water streams. Two important aspects of warm-water stream investigations are lacking: (1) few estimates of total fish population numbers have been made, and (2) fish-collecting methods have not been devised and evaluated for warm-water environments (Larimore 1961). Early interest in and high esteem placed on trout fishing has been the primary cause of more exhaustive cold-water stream studies. Another factor is the greater difficulties encountered in working warm-water streams with their more diversified habitats and larger, more varied fish populations.

## OBJECTIVES

The objectives of this study are to inventory the fish populations of the Tongue River, its major tributaries, and Tongue River Reservoir; to determine species composition, distribution, and diversity indices for various habitat areas occurring in the river system; to evaluate instream flow needs to determine flow levels adequate to protect the fishery; and to evaluate possible impacts of proposed coal development on the Tongue River Reservoir. This task is under the supervision of Al Elser, Montana Department of Fish and Game.

## METHODS

Major habitat zones were delineated for the Tongue River through the use of aerial photos, USGS topographic maps, and on-ground observations. Physical characteristics in each zone will be determined with the aid of the Water Surface Profile Program, developed by the Bureau of Reclamation. This program allows users to predict and/or study various changes in stream characteristics at many different flows. The program model is calibrated to a specific stream section using one or two observed flows, the corresponding water surface elevations, and cross-sectional data at various locations in the stream section (Dooley 1975). These measurements are obtained through standard surveying methods.

Water temperatures were monitored utilizing a Taylor 30-day recording thermograph. The recording sheets were changed monthly. Daily maximum and minimum temperatures were tabulated. All water temperatures were recorded in farenheit degrees.

Aquatic invertebrates were sampled by the Needham kick-screen method to evaluate species distribution. Samples were collected in September and November and were keyed by Bob Newell, Montana Department of Fish and Game.

Fish populations were sampled by several methods. Electrofishing gear with an output of 0-500 volts variable direct current, fished either from a fiberglass boat as described by Vincent (1971) or from the banks of smaller streams, was utilized to sample fish populations in the river and tributaries. Baited hoop nets (wire-frame, 3-foot hoop traps with 1-inch mesh webbing) were fished for channel catfish. Trap nets with 4-foot-by-6-foot frames (1/2-inch and 1/4-inch mesh) were utilized in the Tongue River Reservoir. A 100-foot, 1/4-inch mesh beach seine and a 4-inch bar mesh gill net was also utilized to sample fish populations. Numbered Floy filament tags were used to mark fish.

Fish population statistics were calculated as described by Vincent (1974). Species-diversity indices were calculated according to the formula described by Shannon and Weaver (1964).

## RESULTS

### Physical Parameters

Collection areas were established on 11 reaches of the river downstream from the Tongue River Dam (figure 1). Primary sampling sections (IB, IIB,

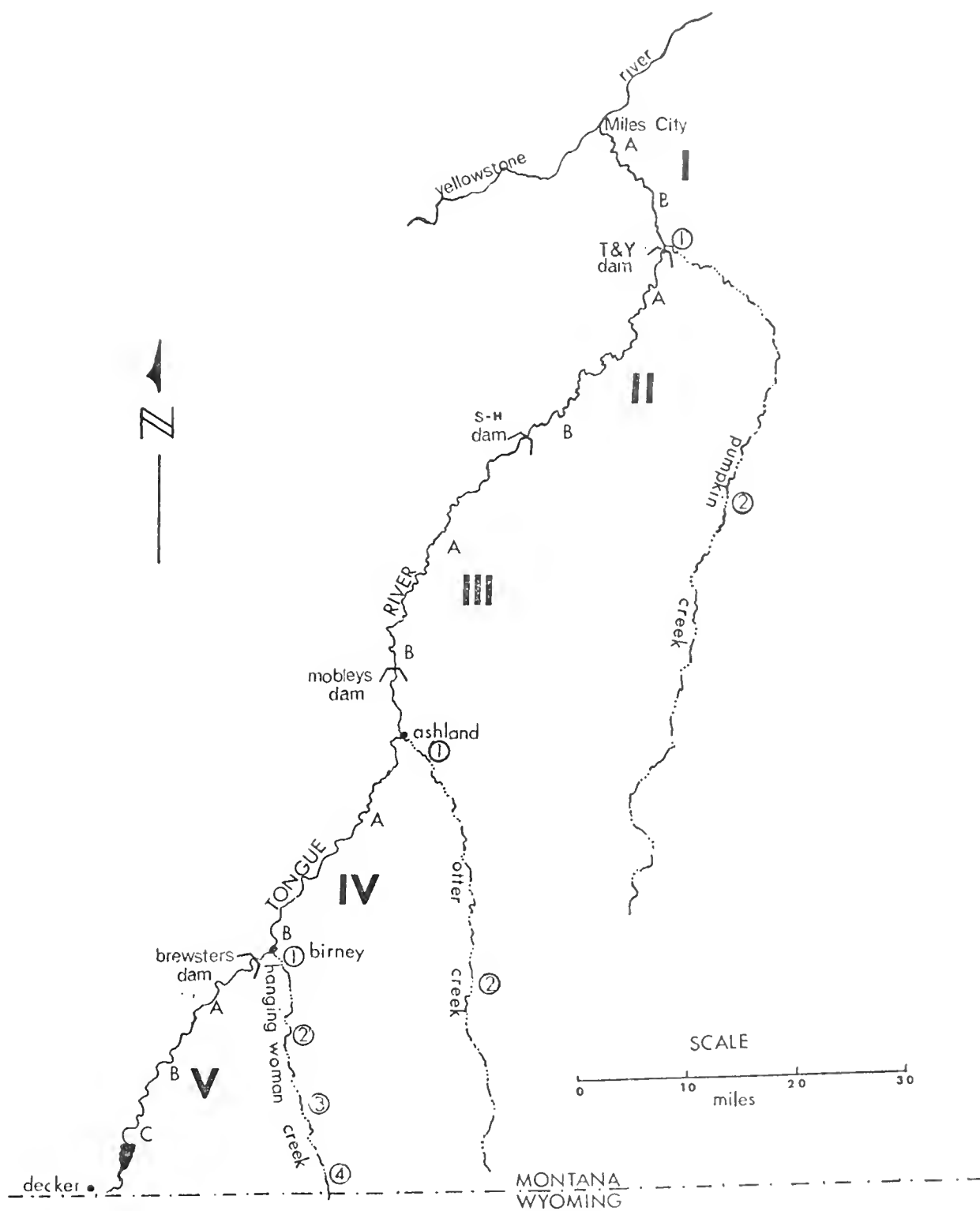


FIGURE 1. Map of the Tongue River, showing sampling sections and major tributaries.

IIIA, IVB, VB, VC) were established in relation to irrigation diversion structures to evaluate fish distribution (table 14). Section VB was established as a major sampling section since the High Tongue River Dam would be located in the section. River sections range in length from 8,200 feet to 13,332 feet, while gradients vary from 2.94 feet/mile near the mouth to 6.67 feet/mile in the canyon. There was a decrease in gradient progressing downstream (figure 2). Secondary sections (IA, IIA, IIIB, IVA, VA) were established to delineate fish distribution in the river.

Water temperatures were recorded at station IA from March to December. Temperatures greater than 70° were recorded for 92 days and 47.8% of those days the temperature exceeded 80°. The maximum temperature recorded was 90° in mid-August. The mean monthly maximum and minimum temperatures are shown in figure 3. Thermographs were installed at stations IIIA and VC.

TABLE 14. Description of major sampling sections, Tongue River.

Section	Location (miles) 1/	Upstream Barrier	Length (ft)	Gradient (ft/mile)
IB	14.1	T and Y Diversion	12,650	2.94
IIB	70.5	S-H Diversion	11,669	3.57
IIIA	90.6	Mobley's Diversion	13,332	4.00
IVB	156.7	Brewster's Diversion	11,669	3.45
VB	177.5	Tongue River Dam	8,870	6.67
VC	186.6	Tongue River Dam	8,200	6.45

1/ River miles above the mouth

#### Fish Population--Tongue River

Species Distribution. Twenty-nine species of fish representing 10 families were collected during 1974 on the Tongue River. Of these species, three (burbot, shovelnose sturgeon and blue suckers) were taken only during the spring sampling near the mouth and are considered to be migrant species.

Qualitative distribution of these species is shown in table 15. Grouping by sections, though it obscures the variation encountered, illustrates broad trends of fish distribution. Six species ranged the length of the stream. Mountain whitefish and brown trout were confined to the upstream zone.

Longitudinal distribution of fish in the Tongue River is influenced by irrigation diversion structures. The T and Y Diversion is the upstream limit for goldeye, walleye, burbot, shovelnose sturgeon, blue suckers, and sturgeon chubs. Channel catfish did not occur above the S-H Diversion. Flathead chubs are found upstream from the Mobley Diversion, but in limited numbers when compared to downstream sections. Brewster's Diversion is the upper limit for river carpsuckers and smallmouth bass.

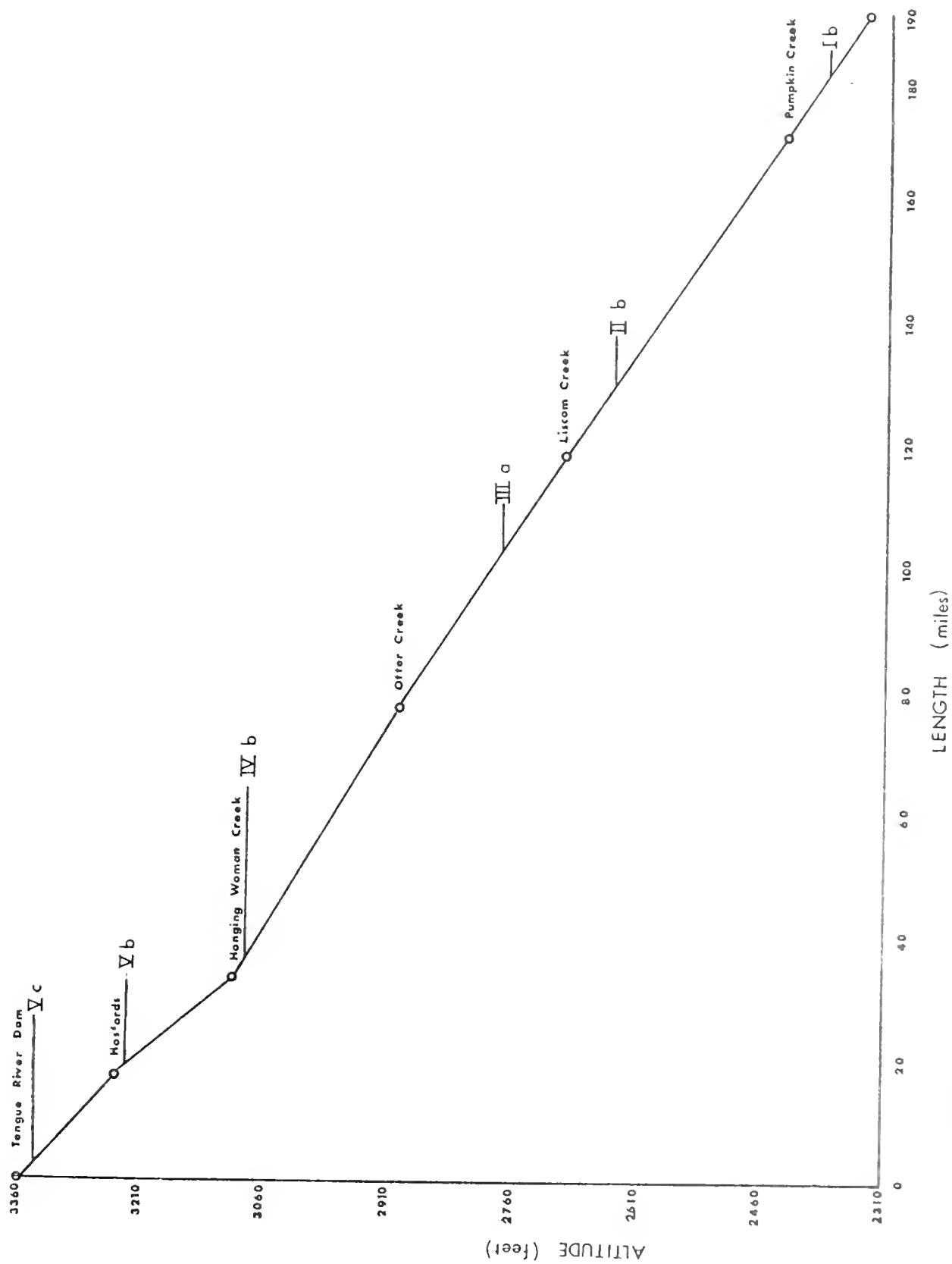




FIGURE 2. Longitudinal profile of the Tongue River from Tongue River Dam to its mouth

 Mean Monthly Minimum  
 Mean Monthly Maximum

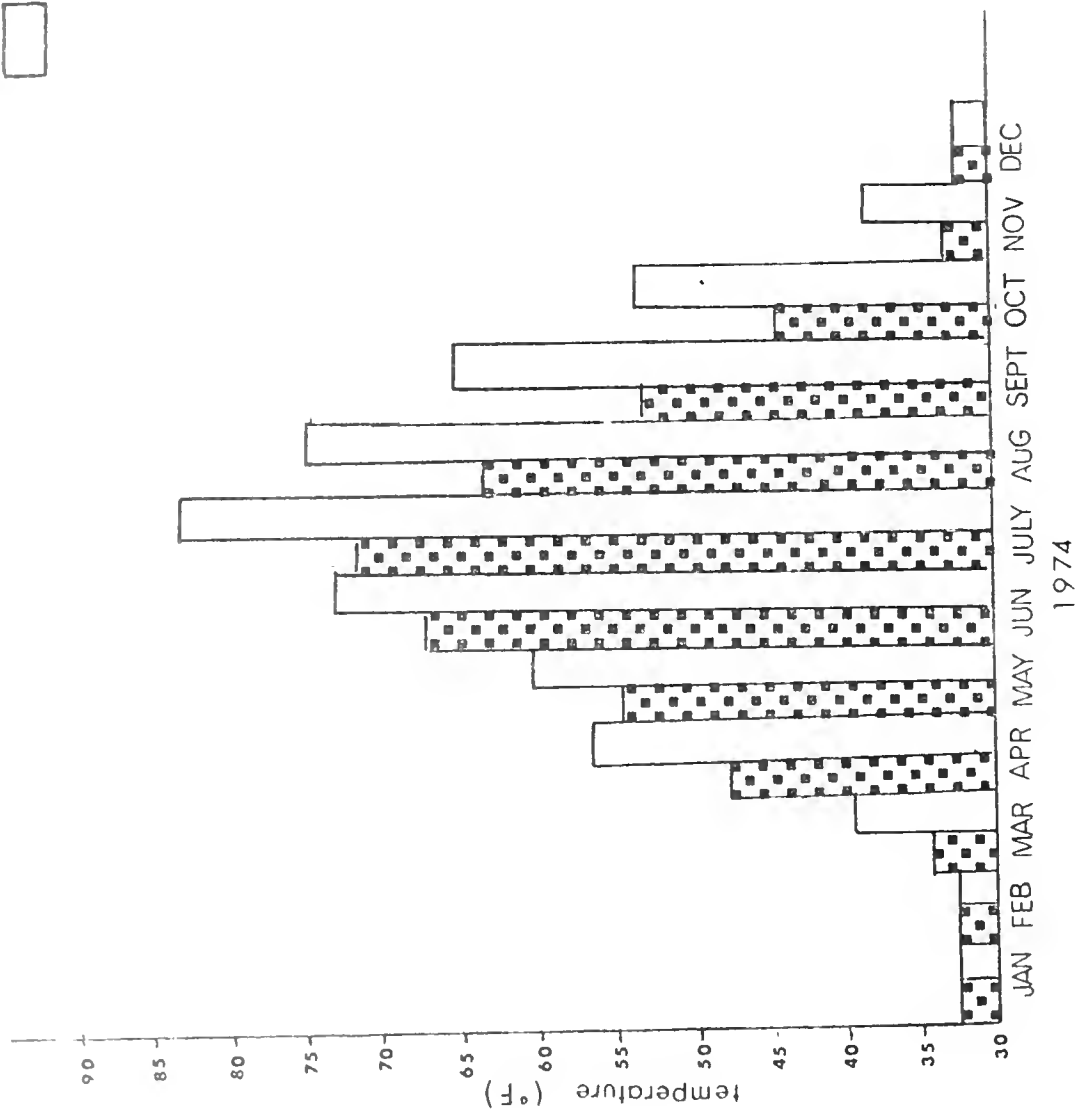


FIGURE 3. Mean monthly maximum and minimum temperatures for the Tongue River, 1974



Common names of fishes used in this report correspond to those presented by the American Fisheries Society (1970).

TABLE 15. Distribution of fishes in the Tongue River by zones, 1974.

Species	Zone				
	V	IV	III	II	I
Carp	*	*	*	*	*
Stonecat	*	*	*	*	*
Shorthead redhorse	*	*	*	*	*
White sucker	*	*	*	*	*
Longnose sucker	*	*	*	*	*
Longnose dace	*	*	*	*	*
White crappie	*	*		*	*
Mountain sucker	*	*	*	*	
Rainbow trout	*	*	*		
Rock bass	*	*	*		
Black crappie	*	*			
Yellow perch	*	*			
Northern pike	*	*			
Whitefish	*				
Brown trout	*				
Green sunfish		*	*	*	
Smallmouth bass		*		*	*
Pumpkinseed		*			*
Black bullhead		*	*		
Flathead chub		*	*	*	*
Sauger		*	*	*	*
River carpsucker		*	*	*	*
Channel catfish				*	*
Goldeye					*
Burbot					*
Walleye					*
Shovelnose sturgeon					*
Blue sucker					*
Sturgeon chub					*
Total No. Species	15	20	14	14	19

Population Numbers and Species Composition. The fall electrofishing samples are summarized in table 16. Estimates of total population numbers and biomass are not completed; therefore, results are expressed as numbers and pounds of fish collected per mile of stream. Each sample is made up of six electrofishing trips. Numerically, flathead chubs were dominant in sections IB (30.1% of the total number) and IIIA (45.7%), followed by shorthead redhorse (19.9% and 20.2%, respectively). Shorthead redhorse were dominant in section IIB (30.9%), and IVB (37.2%). Carp dominated section IB and IIB by weight, while shorthead redhorse dominated sections IIA, IVB, and VC. White suckers dominated section VB both numerically and by weight, and longnose suckers were dominant in section VC. Sucker distribution grades

TABLE 16. Summary of electrofishing samples for the Tongue River, fall 1974, expressed as number of fish per mile of stream (total weight shown in parenthesis)

SPECIES	SECTION					
	TB	IIA	IVB	VB	VC	
Goldeye	33 (17.5)					
Mt. Whitefish				1 (0.2)		
Rainbow trout			1 (0.9)	2 (4.0)	18 (20.3)	
Brown trout					3 (2.6)	
Northern pike			3 (18.8)			
Carp	58 (102.1)					
Flathead chub	133 (6.6)	4 (8.4)	27 (86.4)	33 (16.5)	79 (214.9)	
Sturgeon chub	1 (T)	165 (11.6)	5 (0.3)			
Silvery minnow		2 (T)				
Fathead minnow	3 (T)	15 (0.3)	1 (T)	3 (0.1)		
Longnose dace						
River carpsucker	26 (26.0)		45 (39.2)			
Shorthead redbhorse	88 (69.5)	73 (47.5)	283*(274.5)	14 (15.3)	296 (731.1)	
Longnose sucker	8 (4.8)	21 (16.0)	62 (65.1)	76 (14.4)	770 (1239.7)	
White sucker	8 (6.0)	22 (12.8)	125 (87.5)	311*(307.9)	151 (249.2)	
Mountain sucker		7 (0.4)		1 (0.3)	8 (1.1)	
Black bullhead		1 (0.1)	1 (0.6)			
Channel catfish	7 (18.3)					
Stoner cat	9 (0.6)	41 (3.3)	65 (7.2)	82 (0.8)	34 (4.1)	
Rock bass						
Green sunfish		5 (1.6)	30 (4.2)	11 (1.8)		
Pumpkinseed	1 (0.1)	1 (T)	7 (0.3)			
Smallmouth bass	1 (0.2)		7 (0.1)			
			88 (9.7)			
White crappie	2 (0.3)	2 (0.3)	2 (0.5)	2 (0.2)	1 (T)	
Black crappie	1 (0.1)		1 (0.1)	1 (0.1)		
Yellow perch						
Sauger	58 (56.3)		3 (0.2)	4 (0.4)	10 (0.6)	
Walleye	5 (5.3)	11 (9.9)	5 (4.6)			
Total	442 (313.7)	699 (420.3)	761 (600.2)	541 (362.0)	1370 (2463.6)	
No. of Species	17	16	19	17	11	

from predominately longnose in section VC to white sucker dominance in section VB, with shorthead redhorse dominant in the remaining reaches (figure 4).

Game fish concentrations were heaviest in section IVB and made up 12.7% of the total number, with smallmouth bass the dominant game fish. Smallmouths ranged in length from 2.1 to 13.5 inches and the preponderance of young-of-the-year fish indicates that they are successfully reproducing. Smallmouth bass were also found downstream from the S-H Diversion, but the greatest concentration was near Birney.

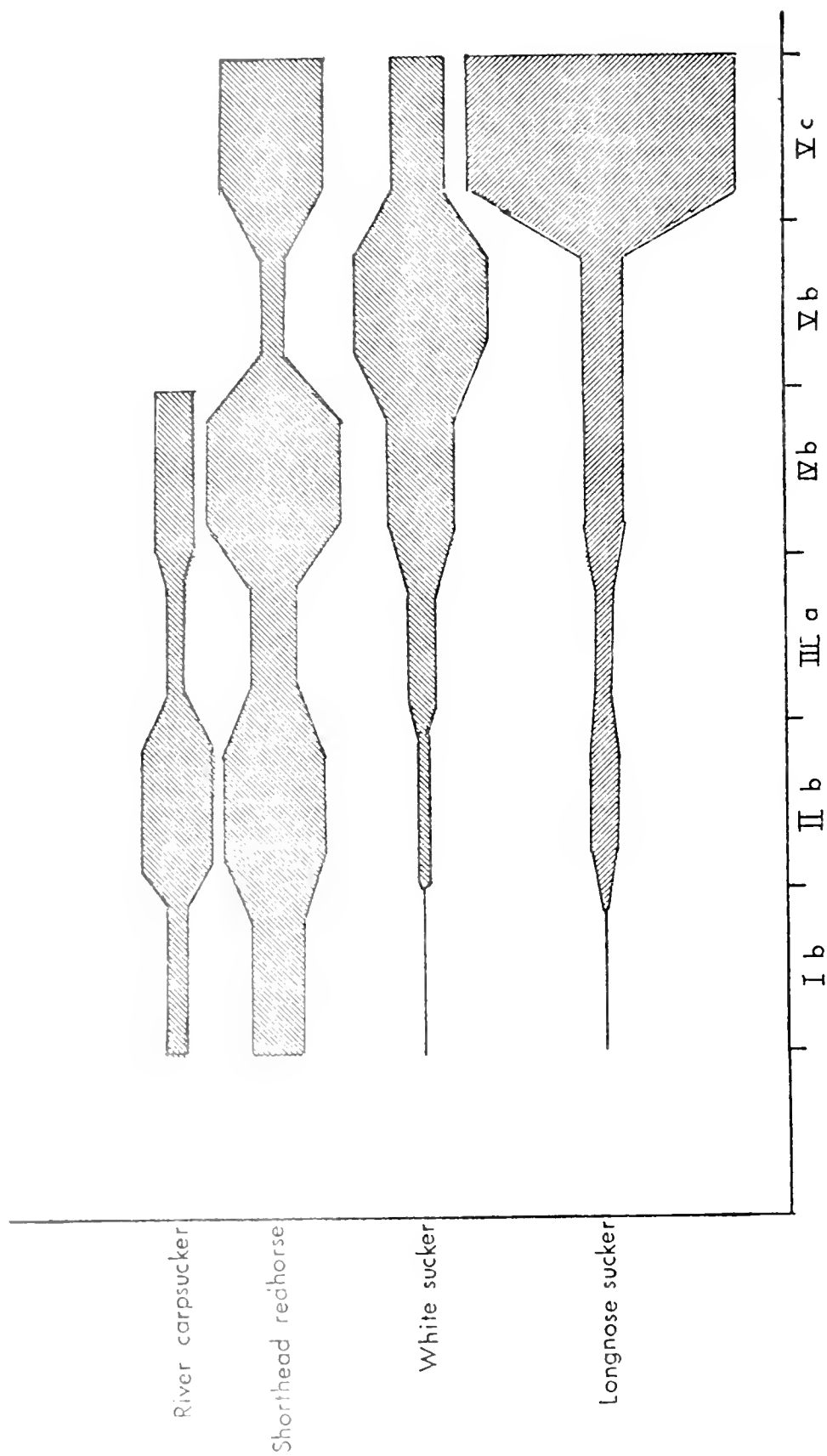
Northern pike were also captured in section IVB. The presence of small northern pikes (9.3 inches in length) suggests that these fish are reproducing in the river. The lower reaches of Hanging Woman Creek would provide excellent northern pike spawning habitat and probably act as a nursery area for the Tongue River population of northern pikes.

The Tongue River supports the only rock bass population in Montana. Greatest numbers of rock bass were found in sections IVB and VB. All size classes were represented in the samples.

The greatest number of channel catfish was found in section IIB, with the largest fish weighing 7.25 pounds. Sauger were most abundant near the mouth, in section IB, and made up 13.1% of the total numbers captured. The largest sauger caught weighed 2.50 pounds.

Species Diversity. Species-diversity indices have been used by biologists to provide insight into the structure of natural communities and as possible indicators of qualitative aspects of their surrounding environments. A low diversity index ( $\bar{d}$ ) indicates a largely monotypic community dominated by a few abundant organisms, while a high diversity index suggests a heterogeneous community in which abundance is distributed more evenly among a number of species. Redundancy (R) is also used as an index of the repetition of information within a community, expressing the dominance of one or more species, and is inversely proportional to the wealth of the species (Wilhm and Dorris 1968).

While species-diversity indices have been used extensively with benthic macroinvertebrates to evaluate degradational environmental conditions, they have recently been applied to fish populations (Sheldon 1968, Jackson and Harp 1973, and Harima and Mundy 1974). Indices of species diversity ( $\bar{d}$ ) and redundancies (R) were calculated for the 6 primary sampling sections on the Tongue River. The diversity indices increased downstream (figure 5), indicating an increase of rarer species in the lower reaches. One exception was section IVB, which did not fit the curve. This section had the greatest number of species, many represented by few individuals. However, as Jackson and Harp (1973) showed, longitudinal distribution in a stream is not necessarily continuous since specific conditions and populations may reappear at intervals throughout the stream system. Redundancy substantiates the  $\bar{d}$  (Shannon-Weaver function) concept, since R increases with dominance by one



#### SECTION

FIGURE 4. Longitudinal distribution of suckers in Tongue River. The width of the line indicates abundance of a species, with the widest place where the greatest numbers were present and can be used as a comparison between species abundance.

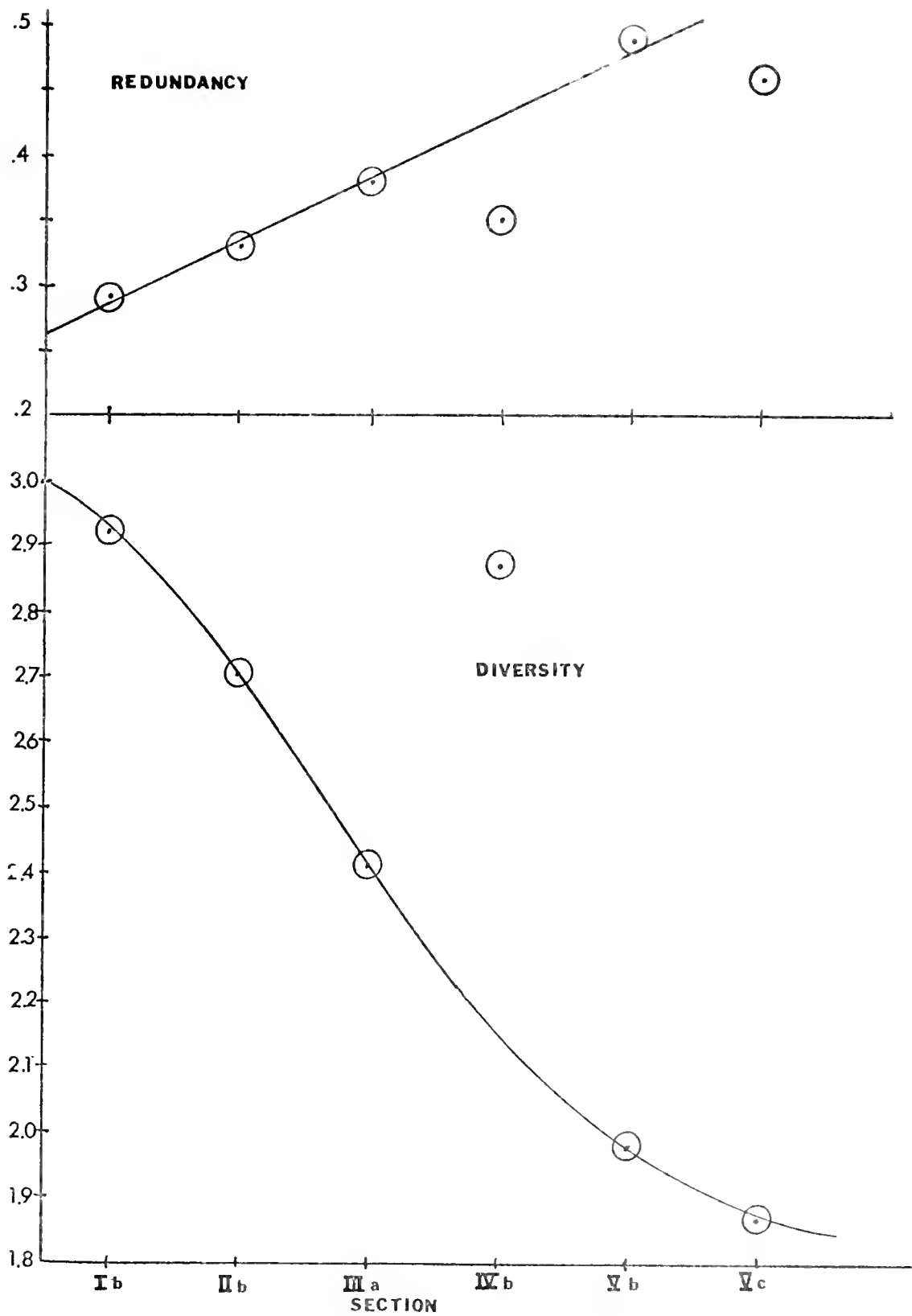


FIGURE 5. Species redundancy and species diversity curves for number of individuals for the Tongue River.

or more species (figure 5). Fish populations in the upstream sections were dominated by one or two species represented by a large number of individuals. And the populations in the lower reaches lack a strongly dominant species.

Measures of species diversity add another handle to the quantitative and qualitative description of a fishery. By collecting baseline data a change in the fish population can be observed by comparing diversity and redundancy. It is generally accepted that environmental stress on a diverse biological community results in a reduction of species diversity (Cairn 1969).

Tagging. A total of 1,060 fish were tagged in the Tongue River during 1974 to evaluate movements and relative angler harvest (table 17). Migrant shovelnose sturgeon, sauger, walleye, channel catfish and other nonsport fish were tagged in the spring in an attempt to determine home ranges of these fish in the Yellowstone River. Of 421 shovelnose sturgeon tagged, only 3 (0.71%) were returned, all from the Yellowstone. Sauger tag returns also were higher in the Yellowstone than in the Tongue (2.33% as compared to 0.33%). The total angler return rate of 1.51% suggests a fishery resource that is being under utilized by anglers.

Age and Growth. Scales were collected from all species taken in the primary sampling sections for a comparison of age and growth. Scales are currently being prepared for analysis and will be worked during the next quarter.

Migrant Fish Populations. Sampling during the spring of 1974 in the lower reaches of the Tongue River (downstream from the T and Y Diversion) revealed a large number of fish moving into the river from the Yellowstone. Sauger, shovelnose sturgeon, and blue suckers moved into the river in sizable numbers. Gonadal development suggested spawning runs were being made by these fish. Sauger concentrations became obvious from fishermen use during mid-April and were present in the river until spring run-off precluded sampling efforts.

The run of shovelnose sturgeon was monitored from April 4 to July 8, with 427 fish captured (Peterman and Haddix 1975). Tagged and released sturgeon numbered 421. Two methods of tagging were used. Serially numbered Floy (FD-67) anchor tags were placed immediately posterior to the dorsal fin and number 3 monel wing band tags were placed over the anterior fin rays of the pectoral fin (Helms 1974).

Shovelnose sturgeon were sampled again in the lower Tongue in 1975. Through June 13, 485 fish were captured, tagged, and released. Sampling is continuing at the writing of this report. The first sturgeon captured in 1975 was taken on May 9, as compared to April 4 in 1974. However, large concentrations of fish were not found in 1974 until around May 9 (Peterman and Haddix 1975). Cooler water temperatures in 1975 may have caused the later arrival of fish. In 1975, numbered Floy (FD-67) anchor tags were placed through the pectoral girdle as described by Helms (1974).

TABLE 17. Summary of fish tagging and angler returns, Tongue River, 1974,  
(Percent returns shown in parenthesis)

Species	Number Tagged	Tongue River	Yellowstone River	Total
Shovelnose Sturgeon	441	-	3 (0.71)	3 (0.71)
Sauger	301	1 (0.33)	7 (2.33)	8 (2.66)
Channel catfish	194	1 (0.52)	1 (0.52)	2 (1.03)
Smallmouth bass	34	1 (2.94)	-	1 (2.94)
Rock bass	33	-	-	-
Rainbow trout	28	1 (3.57)	-	1 (3.57)
Walleye	16	1 (6.25)	-	1 (6.75)
Burbot	11	-	-	-
Blue sucker	11	-	-	-
Northern pike	5	-	-	-
White crappie	3	-	-	-
Bigmouth buffalo	2	-	-	-
Drum	1	-	-	-
Total	1060	5 (0.47)	11 (1.04)	16 (1.51)

Average lengths and weights of sturgeon captured in 1975 were 29.4 inches (fork length) and 5.26 pounds (table 5), and are comparable to fish taken in 1974, 30.2 inches (fork length) and 5.35 pounds. The largest fish taken in 1974 weighed 15.5 pounds as compared to a maximum of 13.25 pounds in 1975. The weight-frequency distribution is also comparable between years. In 1974, 26.0% of the fish weighed six pounds or more, 11.0% weighed 8 pounds or more and 5.0% weighed 10 pounds or more (Peterman and Haddix 1975), as compared to 26.9% greater than 6 pounds, 10.9% greater than 8 pounds and 2.5% greater than 10 pounds in 1975. The Tongue River run appears to be composed of larger fish than reported elsewhere. In the lower Missouri River, the average weight was about one pound, with four-pound fish considered rare (Schmulbach 1974), while the average size reported by Helms (1974) from the Mississippi River was between 2 and 3 pounds. Limited sampling in the Yellowstone near Intake also revealed smaller fish with an average weight of 2.19 pounds (Peterman and Haddix 1975). The larger size of fish in the Tongue may result from sampling a spawning population. Still, the number of fish greater than maximums reported in other areas appears significant.

Tag returns of 1974 fish taken during routine sampling in 1975 totaled 7.4% (31 of 420) through June 13. Of 240 fish tagged with monel tags, 19 (7.9%) have been returned, compared to 6.6% (12 of 180) Floy anchor tag returns. Through June 13, the tag return rate of 485 sturgeon tagged in 1975 was running 5.4%. Angler returns have been slight, averaging less than 0.5%, suggesting low harvest rate.

Monel-tag returns showed that the tag had become completely encased with skin tissue and appeared simply as a raised area on the fin. Calculating growth rate on returned tagged fish revealed that all fish tagged with monel tags had lost considerable weight, while Floy-tagged fish showed weight gain. Eighteen fish returned with monels lost an average of 0.80 pound per fish (range of 0.31 to 3.00 pounds), while 11 fish returned with Floy tags showed

a weight gain of 0.32 pound per fish (range of 0.0 - 0.85 pounds). Apparently metal tags caused a physiological change significant enough to result in a weight loss.

Other fish taken coincidentally with sturgeon sampling were tagged and released (table 18). Tag returns were collected from sauger which had been tagged in 1974. All returns came from approximately the same place they were tagged. Several paddlefish were observed during shocking operations on the lower Tongue. While none were collected due to their large size, their presence in the Tongue River shows the importance of the river.

TABLE 18. Summary of fish sampling in the lower Tongue River, April 23-June 13, 1975.

Species	Number	Average Length	Average Weight	Number Tagged
Shovelnose sturgeon	485	29.6 <sup>1</sup>	5.26	485
Sauger	104	15.2	1.02	39
Channel catfish	37	20.7	4.53	37
Blue suckers	13	27.1	6.56	13
Bigmouth buffalo	12	21.5	6.23	12
Walleye	2	18.5	1.97	2
Northern pike	1	28.2	6.50	1
Smallmouth bass	1	14.8	1.84	1
Ling	1	13.3	0.58	1
Drum	1	19.8	4.28	1
Total	658			643

<sup>1/</sup> Fork length

Passage and spawning flow requirements are important considerations in determining instream flow needs for fish. Apparently a large number of Yellowstone River fish utilize the lower Tongue River as a spawning and nursery area. It will be important to monitor the use of the Tongue by spawning fish to evaluate passage flow needs and to attempt to locate spawning areas to determine spawning needs. Effort will be expended during the next quarter to locate spawning areas and evaluate passage flow requirements.

Fish Populations of Tributaries. Fish populations were sampled in the major tributaries of the Tongue River to evaluate species distribution and species composition. The major tributaries, and the river mile at their confluence with the Tongue, are: Pumpkin Creek, 20.0; Otter Creek, 112.7; and Hanging Woman Creek, 156.7. Two sampling sites each were established on Pumpkin and Otter Creeks and four on Hanging Woman Creek.

The distribution of fish for the tributaries is shown in tables 19 and 20. The stations nearest the mouth in each tributary showed the greatest number of species. Pumpkin Creek had the most species with 12. Most stations had a fauna similar to that found in the mainstem. Exceptions were greatest in Hanging Woman Creek which produced four species not found in the Tongue River.



TABLE 19. Distribution of fish in Pumpkin Creek and Otter Creek, 1974

Pumpkin Creek			Otter Creek Stations		
Species	1	2	Species	1	2
Carp	*	*	White sucker	*	*
Channel catfish	*	*	Pumkinseed	*	*
Goldeye	*		Carp	*	
Flathead chub	*		River carp sucker	*	
Longnose dace	*		Shorthead redhorse	*	
Shorthead redhorse	*		Black bullhead	*	
White sucker	*		Yellow bullhead	*	
Mountain sucker	*		Green sunfish	*	
Stonecat	*		Smallmouth bass	*	
White crappie	*		White crappie	*	
Sauger	*		Yellow perch	*	
Unknown 1	*		Unknown 4		*
Unknown 2		*			
Unknown 3		*			
Total Number species	12	4		11	3

TABLE 20. Distribution of fish in Hanging Woman Creek, 1974

Species	1	2	3	4
Flathead minnow	*	*	*	*
White sucker	*	*	*	*
Green sunfish	*	*	*	
Carp	*	*		*
Lake chub	*		*	*
<u>Hybopsis sp</u>		*		*
Longnose dace		*		*
Black bullhead	*	*		
Yellow bullhead	*	*		
White crappie	*			
Total Number of Species	8	9	4	6

The capture of young northern pike near the mouth of Hanging Woman Creek (Section IVB) suggests that northerns may use the creek as a nursery area. Fish use of the creek was monitored during the spring of 1975 with a temporary fish trap. The leads of the trap were constructed from 1-inch-mesh chicken wire; a frame trap net served as the body of the trap. A total of 134 upstream migrants were taken in the trap. White suckers were predominant (77.6%) followed by carp (9.77%). Other fish taken, in the order of abundance, were: northern pike (5.2%), river carpsuckers (4.5%), shorthead redhorse (2.2%), and green sunfish (0.8%).

The presence of mature northerns of both sexes indicates that the tributary is important to maintaining the integrity of the Tongue River system. The northern pike averaged 23.4 inches in length (range 19.7 to 30.6) and 3.54 pounds in weight (range 2.25 to 7.37). The proximity of the trap to Birney resulted in some piracy of trapped fish. Since northerns and other fish apparently utilize Hanging Woman Creek, it is important to establish in-stream flow standards on the Tongue River and its tributaries.

#### Fish Populations--Tongue River Reservoir

The Tongue River Reservoir and a portion of the drainage upstream were chemically treated in 1957 to remove undesirable fish species. Following rehabilitation, the reservoir was stocked with rainbow trout in an attempt to duplicate fishing which commonly follows the initial impounding of reservoirs. A total of 2,406,824 fingerling rainbow trout were planted during the years 1958-1960. Gill net sampling in November, 1959 produced 80 rainbow trout per net night, while sampling in January, 1960, produced only 7 rainbow per net night. Stocking with trout was stopped because the undesirable fish had again built up to high population levels. However, correspondence in 1962 suggests that the reservoir at that time was still producing some good catches of rainbow trout, with fish from 1½ to 6 pounds being harvested by anglers.

Stocking recommendations for a warm-water fishery implemented in the reservoir in 1963 are summarized in table 21. Northern pike fry and fingerlings were stocked in 1963-1966 to develop a self-sustaining population. No northerns were planted in 1967 and 1968, as a check on natural reproduction, but were again planted in 1969-1974. In 1972, 1973, and 1974, fingerlings were planted, rather than fry, to determine differential survival rates. Channel catfish were introduced in 1963 and 1964, and largemouth bass were planted in 1964 and again in 1972 and 1973. Attempts were made to establish a walleye pike fishery during the years 1965-1969. Since the first plant of walleyes would have matured in 1970, this plant was dropped as a check on spawning success.

Frame trap nets were fished during April, May and June to establish indices of the spawning strength of sport-fish populations. Seven traps were fished a total of 153 nights. The reservoir was divided into three zones (figure 6) and the traps were located in areas that appeared to be good spawning habitat.

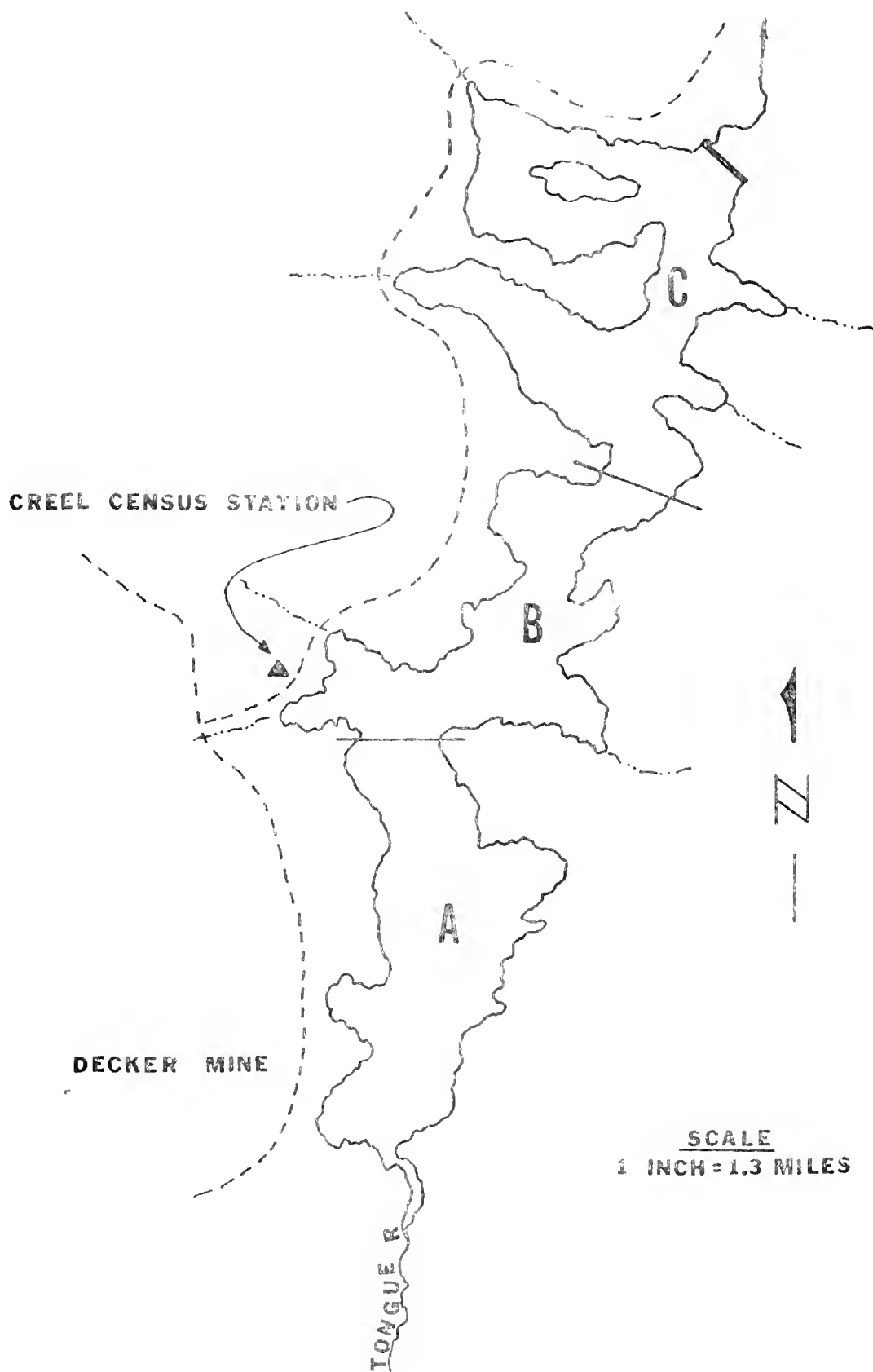


FIGURE 6. Map of Tongue River Reservoir delineating the three sampling zones.

TABLE 21. Summary of warm-water fish plants in the Tongue River Reservoir, 1963-1973.

Year	Species	Size	Number
1963	Northern pike	fry	210,000
	Northern pike	fingerling	35,200
	Channel catfish	3"	20,608
1964	Northern pike	fry	100,000
	Channel catfish	2"	99,180
	Largemouth bass	1"	150,000
1965	Northern pike	fry	339,300
	Walleye pike	fry	750,000
1966	Northern pike	fry	210,500
	Walleye	fry	100,000
1967	Walleye pike	fry	197,750
1968	Walleye pike	fry	601,214
1969	Northern pike	fry	650,000
	Northern pike	fingerling	513,200
	Walleye pike	fry	92,480
1970	Northern pike	fry	1,125,000
1971	Northern pike	fry	360,000
1972	Northern pike	fingerling	14,058
	Largemouth bass	2"	199,290
1973	Northern pike	fingerling	13,184
	Largemouth bass	2"	27,540
1974	Northern pike	fingerling	3,330

Trap net catches for 1975 are compared with catches for 1972, 1973, and 1974 in table 22. Carp, yellow perch and white crappie dominated the catch in 1972, 1973, and 1974, respectively (Elser 1973, 1974). A total of 6,035 fish were captured in 1975 through June 7. White crappie were the predominant fish taken, followed by yellow perch. Traps are still being fished for black and white crappie and smallmouth bass.

Game fish made up 4.8 percent of the total catch in 1975 as compared to 0.7 percent in 1974. Catch statistics of northern pike and walleye are shown

in table 23. Northern pike were taken almost exclusively in zone A with these traps accounting for over 94% of the northern pike catch (table 24). This area with shallow bays is obviously best suited for northern pike reproduction. The increase in northern pike numbers in 1974 and 1975 is assumed due to increased survival of fingerling plants.

The walleye catch was distributed about equally between zones A and B, contributing 42.0 and 39.8 percent, respectively. The remaining 18.2 percent were taken in zone C. Black and white crappie showed distributional patterns, with 46.2% of the blacks being caught in zone C. White crappie were most abundant in zone B (71.0%), followed by zone A (23.7%). Only 5.3% of the white crappie were caught in zone C. This distribution is probably the result of differential water quality between the upper and lower ends of the reservoir.

TABLE 22. Comparison of trap net catches--Tongue River Reservoir, 1972-1975.  
Expressed as numbers per net night.

Species	1972		1973		1974		1975 <sup>1/</sup>	
	No	%	No.	%	No	%	No.	%
Northern pike	0.34	1.78	0.25	1.79	0.95	5.79	1.12	2.83
Carp	7.05	37.10	3.39	24.40	1.46	8.90	4.00	10.14
Goldfish	0.01	0.05	0.02	0.14	0.10	0.61	0.23	0.58
Golden shiner	0.09	0.47	0.11	0.79	0.04	0.24	1.03	2.61
Shorthead redhorse	0.13	0.68	0.21	1.51	0.29	1.77	0.18	0.46
White sucker	0.19	1.00	0.49	3.52	0.30	1.83	0.33	0.84
Longnose sucker	-		0.03	0.21	0.03	0.18	-	
Black bullhead	1.51	7.94	0.43	3.09	0.55	3.35	0.34	0.86
Yellow bullhead	-		-		0.26	1.59	0.36	0.91
Stonecat			0.01	0.07	0.01	0.06	0.03	0.08
Largemouth bass	0.01	0.05	-		0.02	0.12	-	
Smallmouth bass	0.01	0.05	0.01	0.07	0.03	0.08	0.07	0.18
Rock bass	-		0.01	0.07	0.01	0.06	0.05	0.13
Green sunfish	-		0.02	0.14	0.02	0.12	0.05	0.13
Black crappie	1.24	6.52	1.30	9.35	2.99	18.24	4.44	11.26
White crappie	1.99	10.47	3.50	25.19	7.96	48.55	21.71	55.05
Sauger	-		0.02	0.14	0.09	0.55	0.12	0.30
Walleye	0.38	2.00	0.12	0.86	0.33	2.01	0.58	1.47
Yellow perch	6.05	31.84	3.96	28.56	0.96	5.85	4.80	12.17
Total	19.00		13.89		16.4		39.44	
No. Trap nights	85		121		168		153	

<sup>1/</sup> Through June 7

TABLE 23. Average lengths and weights of northern pike and walleye caught in trap nets in the Tongue River Reservoir, 1972-1975.

Year	No.	Northern pike			No.	Walleye		
		Average Length (in)	Range (in)	Average Wt. (lbs)		Average Length (in)	Range (in)	Average Wt. (lbs)
1972	29	29.4	23.5-42.5	8.25	32	19.5	14.1-22.4	2.94
1973	48	28.8	25.5-46.8	8.26	24	21.3	14.3-25.4	3.62
1974	140	28.3	15.5-45.5	6.47	44	20.1	12.0-31.1	3.32
1975	131	31.8	11.1-51.2	6.79	87	18.5	10.6-32.0	2.68

Numbered Floy (FD-67) anchor tags were placed in a total of 424 sport fish to evaluate growth rates, movement and relative fishermen harvest (table 25). One hundred fifty-eight (37.3 percent) tagged fish have been taken in subsequent years during the spring trapping season (table 26). Black crappie returns were highest, with 23 returns out of 38 tagged fish (60.5 percent). All tagged black crappie were large (up to 3.0 pounds) and returned to the trap area in which they were tagged. Northern pike returns averaged 58.8 percent (130 returns out of 221 tagged fish). In 1975, 171 northern pike were captured, of which 89 (52.0 percent) were tag returns, suggesting that a high percentage of the northern population is tagged. Black and white crappie are marked by removing the left pectoral fin. An estimate of population strength will be made using the Schnabel estimator (Ricker 1958).

Of northerns tagged two years ago, 17.1 percent have been returned by anglers; 6.4 percent of northerns tagged one year ago have been returned; overall, anglers have returned 9.3 percent of the northerns tagged over the two-year period. Walleyes tagged in 1974 have shown a 5.9 percent rate of return, while smallmouth bass tagged the same year were returned at a 33.3 percent rate. In 1975, anglers returned three tags within the first two months following tagging. The small rate of tag return suggests harvests well within tolerable limits of the fish populations.

Growth rates were calculated for tagged northern pike, black crappie, and white crappie. Eleven northerns returned two years following tagging gained an average 2.2 inches and 2.20 pounds, while 33 fish recaptured the year following tagging increased in length by 1.9 inches and in weight by 1.54 pounds. One year after tagging, seven black crappie grew an average of 1.1 inches and 0.32 pounds, while one white crappie return gained 0.6 inches and 0.42 pounds in a year.

A creel census was initiated, designed to estimate fisherman use and angler harvest. A creel census station located on the main access road to the reservoir is operated one week day and one weekend day each week. Anglers are interviewed to determine residence, length of fishing trip, and number of fish caught.

TABLE 24. Summary of trap net catches by zone in the Tongue River Reservoir, 1975

Species	April			May			June			Total			
	A	B	C	A	B	C	A	B	C	A	B	C	Total
Northern pike	67	1	1	89	6	2	5			161	7	3	171
Carp	195	23	27	264	53	34	9	7		468	83	61	612
Goldfish	21		1	11	1		1			33	1	1	35
Golden shiner	17	1	1	15	60	8	4	51	1	36	112	10	158
Shorthead redhorse	2			9	5	5	3	2	1	14	7	6	27
White sucker	5		2	1	5	8	2	2	26	8	7	36	51
Longnose sucker	0												
Black bullhead	11	1		13	20	4	1	1	1	25	22	5	52
Yellow bullhead	2			2	33	10	1	5	2	5	38	12	55
Channel catfish	0												
Stonecat	0				3			2			5		5
Largemouth bass					9	1			1		9	2	11
Smallmouth bass					7					1	7		8
Rock bass				1	2	2				3	2	2	7
Green sunfish	2			1				46	283	127	171	382	680
Black crappie	34		2	62	125	97	31	1639	88	787	2358	177	3322
White crappie	83	2		211	717	89	493						
Sauger	2	3		11		2	3	1		13	3	2	18
Walleye	26	31	9	8	3	7	3	12		37	35	16	88
Yellow perch	75	11		9	83	542				87	106	542	735
Total	542	73	43	707	1132	811	556	1768	403	1805	2973	1257	6035
Fish/night	27.1	14.6	14.3	17.2	34.3	35.3	55.6	160.7	57.6	25.8	60.7	38.1	39.44
Trap nights	20	5	3	41	33	23	10	11	7	71	49	33	153

TABLE 25. Summary of tagged fish in Tongue River Reservoir, 1973-1975

Species	1973	1974	1975
Northern pike	41	110	70
Walleye	10	34	76
Sauger	1	9	8
Largemouth bass		2	1
Smallmouth bass	2	3	9
Black crappie		19	19
White crappie		6	4
Total	54	183	187

TABLE 26. Summary of tagged fish returns in trap nets, Tongue River Reservoir, 1973-1975.

Year	Northern pike		Walleye		Black Crappie		White Crappie	
	Tagged	% Ret.	Tagged	% Ret.	Tagged	% Ret.	Tagged	% Ret.
1973	41	75.6	10					
1974	110	68.2	34	8.8	19	57.9	6	16.7
1975	70	34.2	76	1.3	19	63.2	4	
Total	221	58.8	120	3.3	38	60.5	10	10.0

## Discussion

Streams vary greatly in size, velocity, gradient, nature of the bed, temperature, and other features. Generally, streams change from steep torrent to sluggish meandering waterway as they proceed from source to mouth (Allen 1969). Usually there are stages between the two extremes which are characterized by specific environmental features and a particular assemblage of fish species.

Many attempts have been made to associate particular fish faunas with these defined zones. Huet (1959) devised a scheme for European streams using four categories, naming each zone from the characteristic fish species found in them. In descending order of current velocities they are:

- (1) The trout zone
- (2) The grayling zone
- (3) The barbel zone
- (4) The bream zone

Each of these zones is characterized by a particular set of combinations of stream gradient and stream width. North American streams have been classified by zones by Lagler et al. (1962) as follows:

- (1) Grayling
- (2) Stream char
- (3) Flowing water minnows and pike
- (4) Basses
- (5) Catfishes, suckers, and quiet water minnows



As the gradient diminishes, the headwater fishes disappear and are replaced successively by others better adapted to the changing environment.

Fish populations in the Tongue River exhibit a succession from torrent zone fishes (trout) to quiet zone fishes (catfish and suckers). Fish population data suggest that the Tongue River mimics the fish distribution, fish species diversity, and fish species zonation of the Yellowstone River. The results of the Tongue River Study will be compared to fish population studies currently being conducted in the Yellowstone mainstem. This will aid in determining similarities with (or defining differences between) the Tongue subbasin and the entire Yellowstone River Basin.

The objective of the Tongue River Reservoir segment of this study is to obtain baseline information on the fish populations of the reservoir and to document angler use and harvest rates. Decker Coal Company plans to expand mining operations in the near future to include the east side of the reservoir. Questions raised concerning high sodium levels in the soils of the area make it important to evaluate current fish population levels in the reservoir. Fish population data will be coordinated with information collected on a detailed limnology study of the reservoir. This information will make possible the evaluation of the effects of a strip mine in close proximity to a reservoir. Other aspects of energy-related developments will also be investigated and their impacts evaluated.

Task 1 is approximately 40% completed.



TASK 2.    ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON SELECTED MIGRATORY BIRDS. The Grantee shall make a complete analysis of the structure and vegetation of the Yellowstone River from Big Timber to the North Dakota border, with major emphasis being placed upon the islands. The Grantee shall determine the importance of the river system, and altered stream flows, to migratory birds, including but not limited to geese, ducks, bald eagles, and great blue herons. The Grantee shall assess the ecological productivity and importance of this river system from a regional perspective.

## INTRODUCTION

During the period from September 9, 1974, through June 30, 1975, Tom Hinz, Montana Department of Fish and Game, conducted censuses to estimate population levels of Canada geese (*Branta canadensis*), ducks, and other migratory water birds along the lower Yellowstone River. Hinz also studied these birds' food habits, distribution, behavior, and other aspects of their ecology.

## METHODS

Estimates of the population size of each species under consideration were based upon aerial censuses conducted at selected intervals throughout the year. Once the distribution and size of these populations were determined by air, it was possible to study the birds from the ground and by boat.

During aerial censuses conducted on April 22 and 23, 1975, goose pairs were counted in four selected areas north of the Yellowstone River in Treasure, Rosebud, Custer, and Prairie counties. The pair counts obtained from those flights will be used for future stock-pond goose-banding preparations and for records of the goose breeding distribution on those ponds.

Canada geese were the most thoroughly studied species throughout the period. In addition to monitoring population levels, field-feeding populations (including large numbers of migrants) were observed in fields utilized in the fall and spring.

Nesting studies of Canada geese were restricted to four study areas and to a limited number of days of fair weather. In contrast to the seven study areas listed in the Quarterly Report for March 31, it was found that time limited the study of nesting geese to only four areas: one between Hysham and Myers, one between Miles City and the Rosebud-Custer county line (Miles City to Hathaway area), another two miles upstream from the mouth of Sunday Creek (Miles City to Kinsey area), and another from Glendive upstream to above the mouth of Cedar Creek (Glendive to Fallon area). These four areas were studied as closely as time allowed, although the Hysham-to-Myers and Miles-City-to-Hathaway sections were the only ones in which a sizable proportion of nests are believed to have been located. Because of the likelihood that flushing the incubating hen from the nest during cool and rainy

weather will cause chilling of the eggs and subsequent embryonic death, nest searches were not conducted in these areas on days of inclement weather.

Nest histories and physical parameters of goose nest sites were determined whenever possible. In addition, feeding areas were located and subsequent use of these areas and those used for brood rearing was determined.

Canada goose nests were also studied in relation to the vegetational type and the density of cover surrounding the nests. The cover was evaluated using a six-foot board painted black and white in alternating horizontal bands one foot wide, marked with the numerals 1 through 6 from bottom to top. The board was viewed from four points fifty feet from the nest, at right angles to each other; the first point being the most vegetationally open side of the nest. The data obtained by this method will be included in future reports, since nesting histories and similar data were tabulated first.

Two other nest parameters measured at the time the nests were first located were the height of the nest above water and the distance to water. A staff gage was placed in the water near selected nests to facilitate monitoring of water levels at those sites during the nesting season.

Hinz also noted if the water surrounding the nest site was slow, moderate, or fast; if the nest was built on an island, peninsula, or bank; and if the nest was on or above the ground. Also, record was made of what type of substrate the nest was constructed on and whether or not the nest was located near a driftwood log.

Nesting data, including the number of eggs per clutch, average egg dimensions, date of initiation, date of hatching, nesting fate, and other notes were recorded for each nest.

During incubation, selected goose clutches were marked with colored dyes (Evans 1951 and McCabe 1975). Three dye colors, scarlet, blue, and green, were used to facilitate identification of individual broods, or broods from the same island.

After the nesting season, extended efforts were made to locate goose broods and, later, to band young. Estimated brood ages were based on figures in Hanson (1967) and Yocum and Harris (1965). Also at this time, first attempts were made to locate dyed goslings.

Field-feeding observations of dabbling ducks were recorded during much of the study period. Also, observations of breeding ducks along the river were begun in the spring. However, no attempts were made to locate nesting female ducks along the river.

Observations of diving ducks were recorded during the study period in an attempt to determine their relationships to the river system. In the spring, possible breeders were observed and appeared to be only common mergansers (Mergus merganser).

Great blue herons (Ardea herodias) along the river were observed by boat in the latter part of the study period. Breeding pairs in rookeries were counted

from the air. At the same time, observations of the nesting chronology of these pairs were also recorded. One female was collected for food habits analysis.

Double-crested cormorants (Phalacrocorax auritus) were observed by boat in their feeding areas, although none could be collected for food habits analysis. Attempts to locate nesting pairs of this species along the lower Yellowstone were unsuccessful.

Only isolated sitings of bald eagles (Haliaeetus leucocephalus) were recorded during the last three months.

White pelicans (Pelecanus erythrorhynchos) along the river were observed by boat in the spring and collections conducted for food habits analyses. Band returns from two birds were reported and attempts made to determine these pelicans' sex and breeding status.

## RESULTS

### CANADA GOOSE STUDIES

Goose population counts made during the study period are listed in table 27. The highest populations were observed during the fall and spring migration periods. At the time of this report the goose population level was at a low--probably lower than the May census, which was only slightly higher than the overwintering (February) population (table 27). The June census will probably reflect the presence of only successful breeders and their young. Nonbreeding geese, many of which were present at the time of the May census, left the valley to molt by May 27. Large flocks of geese, some numbering up to 50 or more nonbreeders, had gathered in streamside fields to loaf and feed during the breeding season and were no longer present in the valley after this time. This molt migration is typical of the nonbreeding segments of some populations of giant Canada geese (Hanson 1965).

The nesting season, as determined from earliest known dates of nest initiation to latest known dates of hatching, lasted from April 4 or before through June 4 or later (table 28). Back-dating from estimated dates of hatching to estimated dates of nest initiation indicated the earliest nest initiation of March 24 and latest date of hatching of June 5. Based on the earliest estimated dates of initiation and latest estimated dates of hatching (table 28), the duration of the nesting season for the 70 nests studied would be 84 days, a figure similar to that reported by Childress (1971). Based on the first known date of initiation and the last known date of hatching, the nesting season would be 60 days in length, which is brief in comparison to those reported by Geis (1956) and Hanson and Browning (1959), but similar to that reported by Kossack (1950).

Clutch sizes from the nests in which completed clutches were determined are listed in table 29. The mean clutch size for these nests is similar to that reported by Childress (1971) in his and other studies. Childress found no nests of more than seven eggs, but Hanson and Browning (1959) reported what they believed to be a true clutch of 13 eggs laid by one goose.

Eggs from 37 clutches were measured to determine the possible race of those

TABLE 27. Aerial censuses of migratory birds on the lower Yellowstone River between Billings and the Montana-North Dakota border

DATE	GEESE	DABBLING DUCKS	DIVING DUCKS	GREAT BLUE HERONS	DOUBLE- CRESTED CORMORANTS	ADULT		JUVENILE	
						BALD EAGLES	BALD EAGLES	BALD EAGLES	WHITE PELICANS
Sept. 16-17, 74	2,601	3,323	35	127	103	0	0	0	0
Oct. 1-2, 74	3,319	2,272	68	12	52	2	2	2	0
Oct. 15-16, 74	2,854	1,638	57	1	3	5	4	4	0
Nov. 4-5, 74	3,681	17,738	23	0	0	10	4	4	0
Nov. 14-15, 74	5,279	28,146	114	0	0	11	8	8	0
Nov. 25-26, 74	6,873	32,183	829	1	0	25	12	12	0
Dec. 5-6, 74	6,125	33,248	3,272	0	0	72	16	16	0
Dec. 18-20, 74	4,600	32,510	3,334	0	0	63	34	34	0
Dec. 30-31, 74	3,612	19,224	6,160	0	0	35	21	21	0
Jan. 9-10, 75	2,901	17,175	5,812	0	0	32	12	12	0
Feb. 19-20, 75	551	5,707	4,030	0	0	22	5	5	0
Mar. 12-13, 75	16,150	12,835	4,955	0	0	76	41	41	0
April 1-2, 75	13,140	25,863	2,023	12	0	60	37	37	0
April 22-23, 75	975	2,748	122	254	116	1	0	0	424
May 13-14, 75	853	354	24	346	37	0	0	0	271

TABLE 28. Nest initiation and completion dates for seventy Canada goose nests on the lower Yellowstone River, 1975

NEST NO.	DATE OF INITIATION	DATE OF HATCHING*	LOCATION
1	Before 4/5	After 5/8	Bighorn
2	4/10	5/15	Myers
3	4/13	5/18	Forsyth
4	4/13	5/18	Forsyth
5	4/20	5/26	Miles City
6	4/20	5/24	Hathaway
7	4/21	5/27	Hathaway
8	Before 4/18	Before 5/23	Sanders
10	Before 4/18	Before 5/23	Sanders
11	Between 3/29-4/11	Between 5/1-5/15	Hysham
12	Between 4/8-4/20	Between 5/15-5/27	Hysham
13	Before 4/21	Before 5/29	Hysham
15	Between 3/26-4/9	Between 5/1-5/15	Hysham
16	Before 4/23	Before 5/29	Hysham
17	Between 4/9-4/21	Between 5/15-5/27	Hysham
18	Between 3/26-4/8	Between 5/1-5/15	Hysham
19	Between 3/24-4/6	Between 5/1-5/15	Hysham
20	Before 4/17	Between 5/15-5/29	Hysham
21	4/30	6/2	Hysham
22	Before 4/25	Before 5/29	Hysham
23	Between 4/6-4/18	Between 5/15-5/29	Hysham
24	Before 4/23	Before 5/29	Hysham
25	4/10	5/13	Myers
26	Between 4/11-4/26	Between 5/15-5/27	Myers
27	4/12	5/16	Myers
28	4/4	5/14	Myers
29	Between 4/11-4/23	Between 5/15-5/27	Myers
30	Between 4/9-4/21	Between 5/15-5/27	Myers
31	Before 4/27	Before 5/30	Myers
32	Before 4/23	Before 5/30	Myers
33	4/10	5/13	Myers
34	4/28	6/3	Myers
35	Before 4/8	Before 5/12	Myers
36	Before 4/23	Before 5/30	Myers
37	Before 4/24	Before 5/30	Myers
38	Between 3/31-4/9	Between 5/7-5/16	Miles City
39	Between 4/14-4/22	Between 5/20-5/28	Miles City
40	Between 4/9-4/21	Between 5/16-5/28	Miles City
41	4/23	5/26	Miles City
42	4/26	6/4	Miles City
43	4/9	5/17	Miles City
44	Between 4/13-4/21	Between 5/20-5/28	Hathaway
46	4/25	5/29	Hathaway
47	Between 4/4-4/19	Between 5/11-5/26	Glendive
48	Between 4/8-4/23	Between 5/11-5/26	Glendive
49	Between 4/4-4/19	Between 5/11-5/26	Glendive
50	Between 4/2-4/17	Between 5/11-5/26	Glendive
51	Between 3/31-4/14	Between 5/11-5/26	Glendive
52	Between 4/8-4/23	Between 5/11-5/26	Glendive
53	Between 4/5-4/20	Between 5/11-5/26	Glendive
54	Between 4/5-4/20	Between 5/11-5/26	Glendive
55	Before 4/27	Before 6/5	Glendive
56	Between 4/5-4/20	Between 5/11-5/26	Glendive
57	Between 4/6-4/15	Between 5/12-5/21	Kinsley
58	Between 4/3-4/12	Between 5/12-5/21	Kinsley

TABLE 28 (Continued)

NEST NO.	DATE OF INITIATION	DATE OF HATCHING*	LOCATION
59	4/5	5/12	Kinsey
60	4/25	5/29	Kinsey
61	Before 4/15	Before 5/22	Kinsey
62	4/14	5/20	Kinsey
63	4/12	5/20	Kinsey
64	Between 4/21-4/29	Between 5/28-6/5	Kinsey
65	4/16	5/23	Kinsey
66	4/11	5/18	Kinsey
67	Between 4/6-4/16	Between 5/12-5/22	Kinsey
68	Between 4/6-4/16	Between 5/12-5/22	Kinsey
69	4/4	5/11	Kinsey
71	Between 4/5-4/15	Between 5/12-5/22	Kinsey
72	Between 4/8-4/18	Between 5/12-5/22	Kinsey
73	Between 4/24-5/2	Between 5/28-6/5	Kinsey
74	4/14	5/13	Kinsey

\* BACK-DATING AND PROJECTION OF DATES IS BASED ON A CLUTCH OF 5 EGGS; 28-DAY INCUBATION PERIOD (BRAKAGE, 1965), AND 1.5 DAYS PER EGG LAID (KOSSACK, 1950).



TABLE 29. Completed clutch sizes from Canada goose nests on the lower Yellowstone River

NEST NUMBER	CLUTCH SIZE
5	5
8	5
10	5
11	4
12	6
13	7
15	5
16	5
17	5
18	6
19	7
20	9
21	3
22	4
23	7
24	5
25	3
26	4
27	4
28	8
29	4
30	5
31	3
32	6
33	3
34	3
35	4
36	6
38	6
39	5
40	6
42	7
43	6
44	6
46	4
47	6
49	6
50	7
52	3
53	5
54	5
55	9
56	5
57	6
58	7
59	6
60	4
61	6
62	5
64	6
65	6

TABLE 29 (Continued)

NEST NUMBER	CLUTCH SIZE
66	6
67	5
68	5
71	6
72	4
73	4
74	7

AVERAGE CLUTCH SIZE = 5.3  
 RANGE IN CLUTCH SIZE = 3-9

ANY NESTS WITH BROKEN SHELLS OR DUMPED EGGS IN THE VICINITY OF THE NEST WERE  
 OMITTED FROM CONSIDERATION.

nesting pairs (table 30). Egg measurements are believed to be a reliable taxonomic criterion (Hanson 1965), especially in light of the known nesting distribution of the races in question (Rutherford 1965). On this basis, it appears that B. c. maxima does breed in the lower Yellowstone Valley but in this sample comprised only 9 (24.3 percent) of the nesting pairs (table 30).

Success of nests in which clutches were not marked with colored dyes was about 65 percent (table 31). About half of the observed nest failure was due to the flooding of nests, particularly in the study areas from Miles City to Hathaway and from Hysham to Myers. Most of the nests located in the Miles-City-to-Kinsey and Glendive-to-Fallon study areas were successful, largely because none of them were flooded (table 32). The reasons for this may be: 1) no nests were discovered in these areas until after the high water from rains in early May subsided; 2) the increased flows around May 9 and 10 did not markedly increase gage height in these downstream sections where the stream channel is wider; or 3) nests located in these downstream areas are constructed on high islands and high portions of islands. This last possibility may be the result of the ice cover over low islands and bars until late in the nesting season (Hinz 1974).

Success of nests in this study (64.4 percent) was similar to that reported by Dimmick (1968) for Canada geese of Jackson Hole. Variation in this figure is common in other studies and often is in the range of 60 to 65 percent.

Predation and desertion in most of the study areas was a minor cause of nest failure (table 32). Robbed nests usually appeared to have been visited by raccoons or coyotes. At least one nest in the Hysham-to-Myers section was robbed by a red fox. It was not known in any case if predation occurred before or after desertion of the nest.

Clutches marked with colored dyes were omitted from calculations of nesting and egg success because the results of the egg dyeing experiments showed that egg mortality from marked clutches was extremely high (table 33). This mortality is attributed to the process of actually injecting the eggs, although embryos in some marked eggs were later discovered to have been dead at the time of injection. The high mortality of embryos in eggs dyed green (table 33) is believed to have been due to the potency of that dye. It appeared to be toxic in the concentration used even though it was prepared according to Evans (1951) who had success with it.

Of the successful nests listed in table 31, 31 percent contained at least one egg which did not hatch. However, the percentage of successful eggs in successful nests was nearly 90 percent (table 31). This figure is similar to that presented by Geis (1956) who found that 85 percent of the eggs in successful nests hatched. Failure of eggs in successful nests was sometimes due to infertility, but more often it appeared that the embryo died at some stage of incubation. This may have been due to the frequent periods of inclement weather during the nesting season. The frequency of "spoiled" eggs in nests with other viable eggs suggests that the death of embryos in some of the dyed eggs may have been caused by contamination of the injecting syringe by "spoiled" eggs.

Results of the egg-dyeing experiment indicated that blue- and red-dyed eggs were most successful (table 33). Red appears to be inferior to blue in hatchability, but this observation may be biased by the small sample size of blue-dyed eggs (table 33). Red dye was preferred for use from the outset because of the ease of

TABLE 30. Mean length and width in millimeters of Canada goose eggs from nests on the lower Yellowstone River, Spring 1975

RIVER SECTION	CLUTCH SIZE	AVERAGE SIZE	PROBABLE RACE <sup>a</sup>
Hysham to Myers	4	82.4 x 58.9	1
Hysham to Myers	4	88.0 x 57.9	2
Hysham to Myers	8	89.4 x 58.8	2
Hysham to Myers	4	83.5 x 59.3	1
Hysham to Myers	5	84.3 x 55.7	1
Hysham to Myers	5	83.3 x 57.4	1
Hysham to Myers	4	87.8 x 56.4	2
Miles City to Hathaway	5	84.7 x 58.4	1
Miles City to Hathaway	5	86.9 x 58.8	2
Miles City to Hathaway	6	88.8 x 58.2	2 <sup>b</sup>
Miles City to Hathaway	4	84.1 x 57.6	1
Miles City to Hathaway	7	84.3 x 58.1	1
Miles City to Hathaway	6	83.4 x 56.4	1
Miles City to Hathaway	6	82.2 x 58.7	1
Miles City to Hathaway	4	84.6 x 57.5	1
Miles City to Kinsey	6	85.6 x 58.9	1
Miles City to Kinsey	7	82.7 x 57.9	1
Miles City to Kinsey	4	81.0 x 55.3	1
Miles City to Kinsey	6	82.7 x 56.2	1
Miles City to Kinsey	5	83.5 x 57.3	1
Miles City to Kinsey	6	83.3 x 55.5	1
Miles City to Kinsey	6	83.9 x 57.9	1
Miles City to Kinsey	5	82.0 x 56.4	1
Miles City to Kinsey	5	83.7 x 57.2	1
Miles City to Kinsey	4	83.0 x 56.2	1
Miles City to Kinsey	6	80.1 x 57.1	1
Miles City to Kinsey	4	82.1 x 56.4	1
Miles City to Kinsey	4	85.9 x 57.6	1
Glendive to Fallon	6	87.0 x 57.9	2
Glendive to Fallon	3	84.7 x 57.3	1
Glendive to Fallon	6	89.4 x 58.8	2
Glendive to Fallon	7	92.4 x 59.7	2
Glendive to Fallon	9	81.0 x 57.2	1
Glendive to Fallon	3	81.7 x 57.1	1
Glendive to Fallon	5	80.4 x 55.9	1
Glendive to Fallon	9	87.3 x 57.9	2
Glendive to Fallon	5	83.0 x 56.2	1

<sup>a</sup> 1- Branta canadensis moffitti; 2- Branta canadensis maxima  
BASED ON HANSON (1965) AND RUTHERFORD (1965).

<sup>b</sup> PAIR OF THIS FAIR WAS EXTREMELY LARGE WITH A WHITE FOREHEAD SPOT, A COMMON MARKING OF GIANT CANADA GESE (HANSON, 1965).

TABLE 31. Fate of Canada goose nests not marked with colored dyes on the lower Yellowstone River, 1975

NEST #	CLUTCH SIZE	NO. EGGS HATCHED	NO. EGGS UNSUCCESSFUL	FATE	AREA
5	5	0	5	Flooded	Hathaway
11	4	4	0	Successful	Hysham
13	7	0	7	Predated	Hysham
15	5	5	0	Successful	Hysham
16	5	0	5	Flooded	Hysham
18	6	6	0	Successful	Hysham
19	7	7	0	Successful	Hysham
22	4	0	4	Flooded	Hysham
23	7	4	0	Successful	Hysham
25	3	2	1	Successful	Hysham
28	8	0	8	Flooded	Hysham
29	4	4	0	Successful	Hysham
31	3	0	3	Flooded	Hysham
32	6	0	6	Predated	Hysham
33	3	3	0	Successful	Hysham
35	4	0	4	Deserted	Hysham
36	6	0	6	Flooded	Hysham
37	5	0	5	Flooded	Hysham
38	6	6	0	Successful	Hathaway
41	4	0	4	Flooded	Hathaway
43	6	6	0	Successful	Hathaway
46	4	0	4	Flooded	Hathaway
47	6	4	2	Successful	Glendive
48	3	2	1	Successful	Glendive
49	6	5	1	Successful	Glendive
50	7	7	0	Successful	Glendive
51	5	5	0	Successful	Glendive
52	3	3	0	Successful	Glendive
53	5	0	5	Redated	Glendive
54	5	2	3	Successful	Glendive
55	9	0	9	Predated	Glendive
56	5	4	1	Successful	Glendive
57	6	0	0	Predated	Kinsey
59	6	6	0	Successful	Kinsey
61	6	0	0	Deserted	Kinsey
62	5	2	3	Successful	Kinsey
63	6	6	0	Successful	Kinsey
65	6	6	0	Successful	Kinsey
66	6	5	1	Successful	Kinsey
67	5	4	1	Successful	Kinsey
68	5	5	0	Successful	Kinsey
69	6	6	0	Successful	Kinsey
71	6	6	0	Successful	Kinsey
72	4	4	0	Successful	Kinsey
74	7	4	3	Successful	Kinsey

PERCENT NESTS SUCCESSFUL = 64.4

PERCENT EGGS SUCCESSFUL IN SUCCESSFUL NESTS = 88.7

<sup>1</sup> NO. OF EGGS IN UNSUCCESSFUL NESTS UNSUCCESSFUL

<sup>2</sup> NO. OF EGGS IN SUCCESSFUL NESTS UNHATCHED

TABLE 32. Summary of nest fates from four study sections on the lower Yellowstone River

STUDY SECTION	NO. OF NESTS	PERCENT SUCCESSFUL	PERCENT FLOODED	PERCENT PREDATED	PERCENT DESERTED
Hysham to Myers	17	47 (8)	35 (6)	12 (2)	6 (1)
Miles City to Hathaway	5	40 (2)	60 (3)	0 (0)	0 (0)
Kinsey to Miles City	13	84 (11)	0 (0)	8 (1)	8 (1)
Glendive to Fallon	10	80 (8)	0 (0)	20 (2)	0 (0)

<sup>1</sup> EXCLUDING NESTS IN WHICH EGGS WERE INJECTED WITH COLORED DYES WHILE NEST WAS ACTIVE.

TABLE 33. Results of injections of Canada goose eggs with colored dyes on the lower Yellowstone River, Spring 1975

RIVER SECTION	NEST #	COLOR DYE	CLUTCH SIZE	NO. EGGS DYED	NO. DYED EGGS HATCHED <sup>1</sup>	CAUSE OF EGG FAILURE <sup>2</sup>
Hysham-Myers	12	Red	6	6	4	Unknown
Hysham-Myers	17	Red	5	5	0	Unknown
Hysham-Myers	20	Red	9	8	0	Predation
Hysham-Myers	21	Green	3	3	0	Dye Strength
Hysham-Myers	24	Green	5	5	0	Dye Strength
Hysham-Myers	26	Green	4	4	0	Dye Strength
Hysham-Myers	27	Green	4	4	2	Dye Strength
Hysham-Myers	30	Blue	5	5	5	-
Hysham-Myers	24	Red	5	1	1	-
Miles City-Hathaway	39	Red	5	5	4	Infertility
Miles City-Hathaway	40	Green	6	6	1	Dye Strength
Miles City-Hathaway	42	Red	7	5	1	Infertility and/or Eggs Chilled
Miles City-Hathaway	44	Blue	6	6	5	Dyeing Process
Miles City-Kinsey	58	Red	7	7	0	Desertion
Miles City-Kinsey	60	Red	4	4	4	-
Miles City-Kinsey	61	Red	6	6	0	Desertion
Miles City-Kinsey	64	Red	6	6	3	Infertility
Miles City-Kinsey	73	Red	4	4	2	Dyeing Process and Death at

PERCENT BLUE-DYED EGGS HATCHED = 90.9

PERCENT RED-DYED EGGS HATCHED = 33.3

PERCENT GREEN-DYED EGGS HATCHED = 13.6

PERCENT DYED EGGS HATCHED = 35.5

<sup>1</sup> DOES NOT INCLUDE EGGS FOUND IN THE NEST WHICH HAD HATCHED AND LATER DIED OR WERE BROKEN FROM THE SHELL AFTER DEATH BY ACTIVITY IN THE NEST.

<sup>2</sup> UNKNOWN - DYE TEMPERATURE OR OTHER FACTORS

PREDATION - EGGS DESTROYED BY PREDATOR BEFORE OR AFTER DESERTION

DYE STRENGTH - GREEN DYE WAS TOXIC TO EMBRYOS DUE TO CONCENTRATION

INFERTILITY - EGGS INFERTILE BEFORE DYEING; OR CHILLED-EMBRYOS DEAD BEFORE DYEING

DESERTION - OCCURRED BEFORE DYEING IN BOTH CASES.

observing young of this color (McCabe 1975) and the difficulty in distinguishing green- and blue-dyed goslings at longer distances.

By the writing of this report, two dyed goslings had been observed, both from a clutch marked on a midstream island near the Isaac Homestead Game Management Area at Myers. When located, the goslings were about two weeks of age and only 100 yards from the nest in which they hatched. Thus it appears that goose broods on the lower Yellowstone do not always move downstream after hatching as has been reported by Geis (1956), Childress (1971), and Caldwell (1967) in other studies.

Brood observations were begun during the nesting season in areas where nests had been located. The first brood observation was recorded on May 2, when two adults and their five young, then less than a week old, were observed in a backwater in the middle of the Hysham-Myers study area. Of the thirty brood observations recorded between that date and June 12, ten were of broods less than 1 week old, six were of broods 1 to 2 weeks of age, ten were of broods 2 to 3 weeks of age, and four were of broods 4 to 5 weeks of age. Most observations of broods one week of age or younger were recorded before June 1, while most observations of broods one to two weeks of age or older were recorded after that date. The small number of brood observations recorded from May 2 through June 12 is partly because most nests did not hatch until the second or third week in May. Also, broods in these age classes are concealed in streamside vegetation much of the time. No broods observed were classified as three to four weeks of age, probably a result of the brief period of time for which a brood can be observed and an age determination made.

Some brood-rearing areas were located where broods were found out of water. These areas usually exhibited lush green growths of grasses and/or forbs and usually an otherwise open understory. Many of the brood-rearing areas were open, grazed pastures among mature cottonwoods. Some of these areas were also utilized by the pair prior to the start of incubation, and by the territorial male during incubation.

Movement of the brood from the nest may be affected by the velocity of the water past the nest. Of the nest sites for which water velocity was estimated, 13.7 percent occurred by slow or backwater, 49.3 percent by moderately flowing water, and 37.0 percent by fast water. The presence of moderate-to-swift water by the nest, increasing the speed at which the brood can float from danger, may be a factor in nest site selection.

Also related to the security of the nest site is the distance of the nest from the water. Based on measurements at 72 nests, the mean distance to water was 67 feet (20.4 m). The range was from 3 to 413 feet (0.9 to 125.9 m).

Another factor in nest site selection appears to be the substrate on which the nest is to be constructed. Of 73 nest sites in which at least one egg was deposited, 89.0 percent were constructed on a soil, sand, or silt substrate, or some combination of these. The remaining 11 percent were divided equally between wood and rock-sand substrates. Wood substrates occurred as a result of nest construction on a driftwood log or pile of driftwood. Although only about 5 percent of the nests were actually built on a wood substrate, 34.2 percent were constructed immediately adjacent to a driftwood cover.



All of the nests studied were located on the ground or on a log immediately off the ground. However, geese were observed examining aerial nests near Big Horn and Horton, and at least one pair of geese did nest in the Horton heron rookery. Tree nesting by geese, uncommon along the lower Yellowstone, occurs where secure ground nest sites are limited or unavailable. Tree nesting is known to occur along the Tongue River (Knapp 1975), and has been reported by Flath (1970), Craighead and Stockstad (1958), and Dimmick (1968).

Many studies of nesting Canada geese have shown the importance of islands as preferred nest sites. This preference is believed to be a factor in the attractiveness of the lower Yellowstone River to nesting geese. Of the 73 nests in this study in which at least one egg was deposited, all were constructed on land masses which were separated from the main banks of the river by at least a high-water channel.

Heights of nests above water were measured at the time the nests were found, but data on flows from USGS gaging stations at Billings, Miles City, and Sidney are not yet available. A later report will correlate normal spring flows, gage height, and distance of nests above water to determine what conditions will flood a sizable proportion of first nests.

#### DABBING DUCK STUDIES

Numbers of dabbling ducks censused in the study area during this period are listed in table 27. The peak fall and spring populations reflect similar numbers of birds, when field-feeding populations were common in the valley for at least short periods.

Following the departure of the spring migrant populations from the valley, censuses revealed small numbers of mallards and other dabblers still present. Through the spring, dabbling drakes were commonly observed loafing on the river, indicating the likely presence of nesting females nearby in the valley.

Although no duck nests were found along the river, duck nest searches should be conducted after those for goose nests since geese nest earlier. However, the number of dabbling ducks, particularly mallards, nesting along the mainstream Yellowstone is believed to be small. Their nests are probably more common in oxbows, along irrigation ditches, and in vegetation away from the river, probably near more suitable brood habitat.

Mallards were observed utilizing fields in the valley in late spring when hens met with territorial drakes. Mallard pairs were also commonly flushed in backwater areas where the pair members loafed together.

#### DIVING DUCK STUDIES

Study of diving ducks was limited largely to aerial censuses (table 27). Divers along the lower Yellowstone are mainly common goldeneyes (Bucephala clangula) and common mergansers.

As shown in table 27, goldeneye numbers present on the river decreased greatly

by early to mid-April. The remaining diving ducks were mostly common mergansers.

Merganser pairs and drakes were observed along the river in several sections from Glendive to Myers, but no attempts were made to locate nesting females. Actual numbers of breeding pairs are believed to be small.

Other species of diving ducks were observed along the river during the fall and spring migration periods, but since their numbers were comparatively small, they were added to the figures for goldeneyes. Red-breasted mergansers (Mergus serrator) were among the migrant divers present on the river in the spring, but unlike the common mergansers are not believed to breed there.

An adult male common merganser was collected on the river near the Rosebud-Custer county line on April 21. It weighed 3.58 pounds and its crop contents included the pectoral spines of at least three stonecats (Noturus flavus). When collected the bird was fishing on a shallowly submerged point bar, a common feeding area for this species. A subadult female, weighing 2.18 pounds, was collected on a similar bar west of Forsyth on May 29. This bird's crop contained one green sunfish, ten to twenty otoliths, one caddisfly larva, seven unidentified syprinids, and a piece of fishing line and tackle.

#### GREAT BLUE HERON STUDIES

Great blue heron population levels observed during the fall and spring of this study period are listed in table 27, which includes observations of birds on rookeries. The rookeries were censused to determine the number of active nests in each (table 34), though the figures obtained are only approximate because the nests are difficult to count from the air.

Great blue herons and the other large piscivorous water birds left the lower Yellowstone around mid-October, 1974 (table 27). This departure is believed related, at least to some extent, to the onset of colder weather.

Heron rookeries along the lower Yellowstone are constructed in mature cottonwoods, typically located over or near the stream's edge, either on the banks or on the islands. From these areas pair members forage for food up and downstream, and when observed are usually in close proximity to the rookery.

Heron attendance of the rookeries began in late March and early April, when the first herons observed appeared at the rookery near Pompey's Pillar. However, due to the blizzard conditions in the study area for several days in early April, laying did not begin until the latter part of the month. During the aerial census conducted April 22 and 23, nests in some of the rookeries were observed to contain one to four eggs. At this same time, some of the rookeries, including the Horton rookery, were not yet occupied.

The rookeries located near Pompey's Pillar and near Big Horn were the largest ones observed (table 34) and had few inactive nests. Some of the smaller rookeries, including the one east of Horton, had a larger proportion of inactive nests.

Hérons are frequently observed feeding along vegetated banks and shallows at longitudinal and point bars. The crop of a heron collected on May 20 along

TABLE 34. Number of active nests in great blue heron rookeries along the lower Yellowstone River, May 13 and 14, 1975

Location	Nest Site*	Number of Active Nests
Marsh	I	8
Kinsey	B	5
5 Miles East of Horton	B	6
1 Mile East of Sheffield	I	20
Mouth of Sweeney Creek	I	8
2 Miles West of Rosebud	I	5
3 Miles West of Forsyth	I	9
2 Miles East of Hysham	B	11
Mouth of Bighorn River	I	50
7 Miles East of Pompey's Pillar	I	50
Spraklin Island at Huntley	I	35

\* Indicates Bank or Island Location

a vegetated bank west of Miles City contained two flathead chubs (Hybopsis gracilis) and ten to fifteen heads of small syprinids believed to be longnose daces (Rhinichthys cataractae).

#### CORMORANT STUDIES

Double-crested cormorants were present in the lower Yellowstone valley in early fall, 1974, and again beginning in early spring, 1975 (table 27). The individuals present during these periods appeared to be of various ages, as indicated by the dark and the beige plumages exhibited.

Cormorants observed in the lower Yellowstone valley during this period were believed to be nonbreeding individuals. There are no known cormorant rookeries along the lower Yellowstone River.

#### BALD EAGLE STUDIES

Population levels of this species determined during the study period along the lower Yellowstone are shown in table 27. Late spring population levels indicate that this species does not breed along the lower Yellowstone. An adult bald eagle was observed in the Sanders area on April 22 and on May 20, but no nest is known to exist in that vicinity.

#### WHITE PELICAN STUDIES

Censuses of this species during the study period are listed in table 27. Most of the pelican observations occurred downstream from Miles City, although some were observed as far upstream as Custer and Pompey's Pillar.

Three white pelicans were obtained for examination during the study period (table 35). All three of these birds appeared to be in nonbreeding condition. Ovaries from pelicans 2 and 3 were found to contain follicles as large as 22.6 and 37.5 mm in diameter, respectively. Pelican number 1 was too badly decomposed to determine its sex and breeding status. Examination of the crops from pelicans 2 and 3 confirmed their piscivorous feeding habits, but they were largely empty.

TABLE 35. Collection and examination data for three white pelicans taken on the lower Yellowstone River

Collection Number	Date Collected	Location Collected	Sex	Weight	Stomach Contents
1 (found dead)	May 13, 1975	Mouth of Powder River	?	11.25 lb.	-
2 (found dead)	May 14, 1975	Intake	F	12.25 lb.	-
3	May 21, 1975	Savage	F	11.25 lb.	Nematodes Fish hook 5 longnose daces  2 pharyngeal arches of flathead chubs

Two band returns from pelicans found dead in the study area are currently being processed. Data from these returns may indicate their natal or breeding grounds, but their migration routes are still unclear. It appears that the lower Yellowstone River serves only as an extended migrational stop and feeding area for this species.

Percent completion of this task to date is estimated at 40%. Activities planned for the upcoming quarter include: banding of stock-pond and river geese with leg and neck bands, subsequent observation of neck-banded birds, observation of young herons on and off the rookeries, observations of duck broods on the river, censuses of summering bird populations, and collections for food habits work.

TASK 3.     ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON SELECTED FURBEARING MAMMALS. The Grantee shall inventory furbearing mammals along the Yellowstone River from Big Timber to the North Dakota border and determine their relative abundance. The Grantee shall identify the habitat types most important to selected species, including but not limited to beaver, muskrat, mink, and river otter, and assess the impacts of seasonally altered streamflows in each species. The Grantee shall assess related impacts on the supplemental income of individuals engaged in the trapping and sale of these animals.

## INTRODUCTION

The Yellowstone River furbearer study was initiated to determine the potential effects of reduced and/or altered streamflows on furbearing mammals associated with the river system. Primary emphasis is being placed upon the beaver because of their abundance and the fact that their presence is readily ascertained. Peter Martin, Montana Department of Fish and Game, is performing this task.

## METHODS

Beaver caches were located by aerial survey on the Yellowstone River from Big Timber to the North Dakota border, on the Tongue River from the Tongue River Reservoir to its confluence with the Yellowstone River, and on the Bighorn River from Yellowtail Dam to its mouth. Each of these rivers was divided into sections based on the density of beaver caches.

Mean discharges from three stations on the Yellowstone River and one on the Bighorn River were compiled for comparison with historical beaver population data.

Complete lists of persons obtaining trapping permits for the 1974-75 trapping seasons were obtained from Fish and Game regional offices in Billings and Miles City.

Aerial photographs of the Yellowstone and Bighorn Rivers were studied to determine various vegetative types. Use of a "Digitized Planimeter" was investigated for evaluation of habitat availability and usage.

Preliminary measurements of island vegetation area, water and gravel bar area, and total riparian habitat type area on the Bighorn River in 1939 and 1974 were made to determine the feasibility of further study of changes in Bighorn River habitat types attributable to construction of Yellowtail Dam. Visual comparisons indicated that gravel bar areas have diminished and the number of vegetated islands has been greatly reduced.

## RESULTS

### INVENTORY OF ANIMALS

Fur harvest parameters (numbers taken, numbers of trappers, average catch per trapper, and average pelt price) for beaver, mink, and muskrat in Fish and Game Regions 5 and 7 for harvest seasons 1960-61 through 1972-73 were subjected to linear regression analysis. The resulting correlation coefficients (r), the measure of mutual relationships between two variables (Snedecor and Cochran 1967), are presented in table 36.

There is a definite positive relation between the numbers of furbearers trapped and the average catch per trapper (efficiency), as all three species in both regions show correlation coefficients (r) significant at the  $p=.01$  level. Generally, the number trapped is significantly related to the number of trappers ( $p=.05$ ) with only muskrat in Region 5 showing an r not significant (0.571; a value of 0.576 was needed to be significant at  $p=.05$ ) (Snedecor and Cochran 1967). Only mink numbers trapped showed a significant relation to the average pelt price.

TABLE 36. Correlation coefficients of multiple linear regression analysis of numbers of furbearers trapped in Fish and Game Regions 5 and 7 compared to numbers of trappers, average catch per trapper, and average pelt price.

		Numbers of Trappers (10) <sup>a</sup>	Catch per Trapper (12)	Average Pelt Price (12)
Beaver	R-5	0.896 ** b	0.883 **	-0.039
	R-7	0.607	0.859 **	0.046
Mink	R-5	0.911 **	0.964 **	0.676 **
	R-7	0.704 *	0.934 **	0.662 **
Muskrat	R-5	0.571	0.942 **	0.267
	R-7	0.845 **	0.823 **	0.418

a - Degrees of freedom (7-1) determined by number of years of compatible data.

b - Statistical significance ( $p=.05^*$  and  $p=.01^{**}$ ) of correlation as determined by Snedecor and Cochran (1967).

This analysis indicates that the number of furbearers taken is primarily dependent on two factors: the number of animals available and the efficiency of trappers. The efficiency of trappers varies with individuals, and the probable overriding factor is the availability of the furbearing species to be harvested--i.e., the higher the numbers of a particular species, the easier it will be for trappers to catch them, resulting in a higher average catch per trapper.

The distribution of trout among anglers in a study of catchable trout fisheries (Butler and Borgeson 1965) showed that 50 percent of the catch was taken by less than 10 percent of the fishermen. A study of the distribution of harvest among fur trappers would probably result in a similar result. Some trappers are simply more efficient than others. For this reason, the number of trappers is not as significantly related to numbers taken as is overall efficiency, or catch per trapper. If only a few of the small percent which harvested much of the fur were unable to trap or chose not to for some reason, numbers trapped could be significantly reduced. One reason for not trapping might be monetary reward, as reflected in average pelt prices. Only mink numbers trapped showed a significant relationship to the average pelt price. However, only about 44 percent of the variance in mink numbers trapped can be attributed to changing pelt prices. This indicates that a large percentage of the catch is taken regardless of monetary benefits received by the trappers. In other words, trapping is done for the recreation involved as well as for monetary rewards.

#### EFFECT OF TRAPPING ON INCOME

The following list of questions was prepared for personal interviews with trappers:

1. What species have you trapped?
2. In which years have you trapped?
3. What are the limits of your trapping area?
4. Where are the highest densities found for the various furbearing species?
5. What constitutes good (optimum) habitat for the various furbearing species?
6. How much time do you devote to trapping (setting traps, checking them, preparing skins)?
7. To whom do you sell your pelts?
8. How much do you depend on the income from fur trapping?
9. How do you think regulating flows on the Yellowstone with dams and/or diversions would effect the various furbearing species?

Average dollars per trapper per species and total dollars realized from the sale of pelts for Regions 5 and 7 are shown in table 37.

#### IMPACT OF ALTERED STREAMFLOWS

The number of furbearers trapped were compared with flow data on the Yellowstone River. Flows at Billings were compared with numbers taken in Region 5, while flows at Miles City were compared to numbers taken in Region 7. Flows

TABLE 37. Average dollars realized per trapper per species and total dollars per species in Fish and Game Regions 5 and 7

SEASON	BEAVER		MINK				MUSKRAT					
	REGION 5		REGION 7		REGION 5		REGION 7		REGION 5		REGION 7	
	1'	2'	1	2	1	2	1	2	1	2	1	2
1960-61	23,324.00	285.72	14,239.00	261.82	11,412.72	119.79	1,660.36	48.36	1,345.50	14.26	192.60	6.75
1961-62	16,569.00	190.68	9,503.00	140.35	7,366.42	79.02	2,240.60	65.90	2,230.00	34.20	355.24	19.92
1962-63	21,462.00	291.27	17,283.00	353.89	11,511.50	120.12	8,830.95	254.25	6,708.42	69.69	972.04	21.28
1963-64	7,795.00	120.98	5,528.77	118.14	16,555.40	166.91	5,821.76	155.04	2,995.74	32.75	1,096.00	24.88
1964-65	6,104.70	127.40	2,163.84	89.06	7,005.63	74.72	2,219.14	92.22	2,340.92	28.55	146.73	8.24
1965-66	5,052.84	132.72	13,438.74	336.48	9,662.08	97.22	2,686.86	103.22	2,669.65	36.59	639.84	31.99
1966-67	8,901.79	155.97	5,234.06	137.48	5,905.20	72.96	1,351.25	64.63	1,412.43	18.56	85.80	5.35
1967-68	11,502.07	173.29	7,522.15	206.78	3,283.38	45.29	1,394.64	58.97	498.00	7.32	227.88	7.99
1968-69	13,332.81	216.55	8,924.38	198.90	4,204.20	79.77	1,921.92	92.09	1,131.63	16.82	984.20	33.74
1969-70	16,999.50	196.35	8,905.10	158.53	3,640.88	44.87	1,659.84	61.26	1,905.30	19.53	1,105.28	27.28
1970-71	8,977.36	179.93	3,108.45	96.99	1,053.15	24.78	612.75	35.48	959.04	16.80	335.67	15.75
1971-72	12,532.35	185.50	8,101.98	236.43	1,069.26	21.08	587.40	32.31	1,539.73	23.75	349.74	14.84
1972-73	29,101.96	243.97	24,392.96	291.99	2,343.09	33.88	3,564.90	102.51	4,110.08	37.54	2,419.22	43.07

1/ Total value of pelts - number trapped x average pelt price

2/ Average dollars realized per trapper - average catch per trapper x average pelt price.



from the calendar year and the current water year (those which occurred during the trapping season), the months of October and January (also during the trapping season), and during the previous water year were used in the analysis. The results of the multiple linear regressions, expressed as correlation coefficients, are shown in table 38.

With only a few exceptions, numbers trapped showed a negative relationship (i.e. high flow, low numbers trapped) that was not statistically significant ( $p=.05$ ) to flow. Beaver trapped in Region 5 showed the only significant relationship to flow with  $p=.01$  in the current calendar year and  $p=.05$  in both current and previous water years and during the October just prior to the trapping season. Only 39 percent ( $r^2$ ) of the variation in numbers trapped could be attributed to the flow during the calendar year which showed the most significant relationship.

Mink and muskrat numbers trapped were not related to these flow parameters. While mink relationships were generally negative, those of muskrats were almost evenly mixed between positive and negative slopes, with Region 5 negative and Region 7 positive.

Beaver population figures obtained by Montana Fish and Game Department personnel were compared to flow data on the Bighorn River and three sections of the Yellowstone River (table 39). Although the degrees of freedom are very small for the Bighorn River and the Billings section of the Yellowstone, miles of river per beaver cache show a positive, generally significant ( $p=.05$ ) relationship to flow in both the previous water year and current calendar year. This indicates a negative relationship between flow and population numbers. In other words, as flow increases, the number of river miles per cache also increases. As the number of river miles per cache increases, the total number of beaver decreases. The percentage of significant variation ( $r^2$ ) attributable to flow varied from 48 percent to 98 percent. This is only a preliminary analysis and may change when data gathered during this study are included.

Overlays of 1939 and 1974 aerial photographs of the Bighorn River depicting vegetated islands, gravel bars, bank riparian vegetation and river bed were completed. Each series was divided into five sections for comparison. River length, total riparian area, total river area (including vegetated islands, gravel bars, and water), individual vegetated island area, and individual gravel bar area was obtained with the "Digitized Planimeter". Overall length of the Bighorn River has decreased from 103.7 miles to 86.0 miles--a 17.1 percent reduction. Total riparian area has decreased 11,159.2 acres, or 33.5 percent. Total river bottom (water, gravel bars, and islands) area has decreased 50.1 percent. Total bank riparian area has decreased 7.5 percent. Changes in each section are shown in table 40.

The estimated percentage of task 3 completion is 50%.

An effort to complete personal interviews of trappers will be made during the next quarter. Final analysis of Bighorn River alterations will also be made.

TABLE 38. Correlation coefficients of multiple linear regression analysis of numbers of furbearers trapped in Fish and Game Regions 5 and 7 compared to various flow parameters taken at the Billings and Miles City recording stations.

		During Trapping Season			Prior to Trapping Season	
		Calendar Year (15) <sup>a</sup>	Water Year (15)	January (15)	Water Year (10)	October (15)
Beaver	R-5	-0.623** <sup>b</sup>	-0.488*	+0.280	-0.605*	-0.509*
	R-7	-0.244	-0.471	-0.368	-0.210	-0.172
Mink	R-5	-0.232	-0.314	-0.038	-0.389	-0.188
	R-7	-0.167	-0.154	-0.330	+0.089	-0.310
Muskrat	R-5	-0.282	-0.068	-0.158	-0.150	-0.328
	R-7	+0.252	-0.039	+0.193	+0.353	+0.203

a - Degrees of freedom (7-1) determined by number of years of compatible data.

b - Statistical significance ( $p=.01^{**}$  and  $p=.05^{*}$ ) of correlation as determined by Snedecor and Cochran, table A11, page 557.

TABLE 39. Correlation coefficients of beaver population data (miles per cache) as related to flow data on the Bighorn River and three sections of the Yellowstone River determined by multiple linear regression analysis.

	FLOW <sup>c</sup>		Degrees of Freedom <sup>b</sup>
	Water Year	Calendar Year	
Bighorn	0.983* <sup>a</sup>	0.999**	2
Yellowstone			
Billings	0.554	0.455	2
Miles City	0.744*	0.694	7
Sidney	0.820**	0.790**	8

a - Significance of correlation coefficient ( $p=.01^{**}$  and  $p=.05^{*}$ ) as determined by Snedecor and Cochran, table A11, page 557.

b - Degrees of freedom (n-1) determined by number of years of population data used in analysis for each section of river near the various flow recording stations.

c - Flow data used for each station were those of the water year ending prior to beaver cache counts (made in late October and early November) and the current calendar year.

TABLE 40. Changes in parameters of Bighorn River bottom from 1939 to 1974 as determined by measurements utilizing a "digitized planimeter"

	1939	1974	Change	Percent
Length of main channel in miles				
Section 1	15.49	12.17	-3.32	-21.4
2	24.68	19.82	-4.96	-19.7
3	25.32	20.30	-5.02	-19.8
4	24.59	18.91	-5.68	-23.1
5	13.63	14.77	+1.14	+ 8.36
Total	103.71	85.97	-17.74	-17.1
Total riparian area in acres (includes entire river bottom minus farm land and other developments).				
Section 1	4,616.06	3,197.41	-1,418.65	-30.7
2	8,665.38	5,516.61	-3,148.77	-36.3
3	9,324.23	5,486.22	-3,838.01	-41.2
4	7,136.36	4,458.89	-2,377.47	-37.5
5	3,546.69	3,470.42	-76.27	- 2.2
Total	33,288.72	22,129.55	-11,159.17	-33.5
Total bank riparian area in acres				
Section 1	2,475.35	2,232.25	-243.10	- 9.8
2	4,056.67	3,528.83	-527.84	-13.0
3	3,046.29	2,761.91	-284.38	- 9.3
4	2,001.83	1,981.81	- 20.02	- 1.0
5	1,590.59	1,675.96	+85.37	+ 5.4
Total	13,170.73	12,180.76	-989.97	- 7.5
Total river area in acres (includes water, islands and gravel bars)				
Section 1	2,140.71	985.16	-1,175.55	-54.9
2	4,608.71	1,987.78	-2,620.93	-56.9
3	6,277.94	2,724.31	-3,553.63	-56.6
4	5,134.53	2,477.08	-2,657.45	-51.8
5	1,956.10	1,794.46	-161.64	- 8.3
Total	20,117.99	9,948.79	-10,169.20	-50.1



TASK 4. ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON AGRICULTURE WHICH IS DEPENDENT UPON IRRIGATION. The Grantee shall estimate the future demand for agricultural projects provided by irrigated farming. The Grantee shall project what further irrigation development could occur in the study area on the basis of the existing resource base. The Grantee shall ascertain and, insofar as possible, quantify potential physical and economic constraints that may result from the use of water for coal development.

#### IRRIGABLE LANDS ANALYSIS

Philip Threlkeld, with the help of Glenn Smith, Elna Tannehill, and Mike Brown, all of DNRC, worked on this task.

The DNRC general reconnaissance land classification system was used to identify and locate the irrigable lands in the Yellowstone Basin. This system evaluates the land's ability to sustain irrigated agriculture and classifies the land according to its productive value:

1. Irrigable land
  - a. High productive value (Class 1)
  - b. Intermediate productive value (Class 2)
  - c. Low productive value (Class 3)
2. Nonirrigable land (Class 6)

The term "irrigable land" as used in this classification includes land that is appropriate for irrigation by either gravity or sprinkler methods. The classification is based on similarity of characteristics such as soils, topography, and climate, and disregards both the present available water supply and economic constraints to irrigation.

Based on this system, there are over 2.2 million acres of irrigable land in the Yellowstone Basin. However, much of this land does not have an adequate water supply, and because both technical and economic constraints limit irrigation to areas within reach of an adequate water supply, these constraints must be considered when estimating future irrigation.

A preliminary tabulation was made incorporating technical limitations. These constraints were arbitrarily set, and can be modified as more accurate information becomes available. Their primary purpose was to limit the size of the area to be studied. The technical limitations used for the preliminary tabulation are:

1. All water comes from the Yellowstone River, or its major tributaries:

- a. Powder River
- b. Tongue River
- c. Bighorn and Little Bighorn Rivers
- d. Clarks Fork of the Yellowstone

2. Maximum pipeline length is 15 miles

3. Maximum pump lift is 700 ft/pump

Table 41 summarizes the preliminary tabulation. The irrigable land was classified into "phases" according to pipeline length and pump lift.

Phase I includes all land within 1 mile of the river or an existing irrigation structure. This land is generally situated along the floodplain and is intermingled with presently irrigated land. Expansion of the present facilities or construction of short pipelines could bring an additional 247,659 acres under irrigation.

Phase II includes all land within 5 miles of the river requiring a vertical lift of no more than 700 feet. Most of this land occurs on the benches above the river. Sprinkler irrigation is currently being used on some of these benches, with pump lifts of up to 450 ft. (Montana DNRC 1975). 356,537 additional acres can be irrigated on these benches. However, more complete technical and economic information is needed to determine the amount of irrigation that is likely to be developed.

Phase III includes land that is more than 5 miles from a water supply, requires more than one pumping station (700 ft. lift/pump), or requires a siphon to cross gullies. Many of these areas are located along small tributary streams and are intermixed with presently irrigated land. The potential for expansion is limited unless supplemental water is obtained from the Yellowstone River or its major tributaries. Complete economic and technical analysis is needed to determine the feasibility of irrigating Phase III land. An additional 192,849 acres can be irrigated if these areas are feasible.

A computer program has been developed by Mike Brown to help evaluate the technical and economic limitations of water delivery systems. This program is designed to compute the cost of pumping water to a highline ditch for each irrigation project. Construction costs for a highline ditch will then be added to the pumping costs to determine the total price of water delivered to the farm gate for each project.

Farm budgets will be used to determine the price farmers can pay for water under various commodity price conditions, cropping patterns, and irrigation systems. The U.S. Bureau of Reclamation has developed farm budgets for the entire Yellowstone Basin. These budgets are being used as guidelines for developing a version that is compatible with the computer program and which provides the necessary information for comparing water delivery costs to the farmers' ability to pay for water.

#### CROSS-SECTION SURVEY

In order to evaluate the effects of changes in streamflow on diversions in the Yellowstone River Basin, several sites have been chosen where cross sections of the rivers will be surveyed. These are:

TABLE 41. Irrigable land in the Yellowstone Basin, by county (in acres)

County	Phase			Pump Lift (feet)							Total
	I	II	III	0-100	100-200	200-300	300-400	400-500	500-600	600 +	
Big Horn	15,915	79,474	28,556	17,111	14,991	19,390	24,522	16,079	16,799	15,053	123,945
Carbon	19,617	11,712	7,873	19,617	0	624	832	7,953	10,176	0	39,202
Custer	43,007	16,683	0	43,007	0	4,660	5,881	6,142	0	0	59,690
Dawson	10,228	32,976	28,644	10,228	1,870	0	2,729	34,252	19,936	2,833	71,848
Park	28,610	14,132	3,012	28,610	906	4,856	716	2,107	1,097	7,462	45,754
Powder River	41,127	25,654	26,767	46,184	3,144	4,731	5,977	30,974	2,538	0	93,548
Prairie	6,565	34,092	3,088	6,565	1,429	8,306	11,584	15,861	0	0	43,745
Richland	7,836	15,718	41,093	8,706	2,792	5,431	7,049	23,511	17,158	0	64,647
Rosebud	17,973	36,675	15,642	21,888	1,825	1,054	8,357	19,451	4,103	13,612	70,290
Stillwater	13,317	2,681	0	13,744	2,254	0	0	0	0	0	15,999
Sweetgrass	13,570	8,867	1,448	13,570	0	346	0	0	7,010	2,959	23,885
Treasure	11,886	18,749	11,170	11,886	4,379	2,857	15,964	6,719	0	0	41,805
Wibaux	368	0	0	368	0	0	0	0	0	0	368
Yellowstone	17,640	59,124	25,556	17,640	4,424	14,884	13,939	9,942	17,264	24,227	102,320
TOTAL	247,659	356,537	192,849	259,124	38,014	67,139	97,550	172,991	96,081	66,146	797,045
% of TOTAL	31	45	24	33	5	8	12	22	12	8	

1. Sidney Pumping Plants 1, 2, and 3.
2. Buffalo Rapids Project-Kinsey Ditch.
3. Glendive City Water Supply.
4. Billings City Water Supply and Coulsen Ditch.
5. Forsyth Diversion Dam.
6. Rancher Ditch.
7. Hugo Muggli Pump (Tongue River).
8. Victory Ditch (Bighorn River).
9. Bighorn Low Line Canal.

Several cross sections are taken at each site so that water surface profiles can be generated. To date, the field work has been completed on the Sidney, Kinsey, and Forsyth sites, and surveying of control points has been started on the Glendive and Hugo Muggli sites. Drafting is also complete on the Sidney sites. Along with the cross sections, books have been prepared for each agency involved in the study showing the sites of interest to each participant.

Task 4 is approximately 35% completed.

Work schedules for next quarter include:

1. Completion of farm budgets.
2. Determination of highline ditch requirements for each project.
3. Continuation of cross-section surveys.



TASK 5. ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON MUNICIPAL AND NON-ENERGY INDUSTRIAL WATER SUPPLIES. The Grantee shall identify existing uses and sources of supply. The Grantee shall project future water needs for existing municipalities and for selected developing communities. The Grantee shall then assess the effects of water storage and diversion upon each community.

### METHODOLOGY

Future coal and energy-related development must be projected before population levels can be estimated. When these two elements are completed, the "impacts of altered stream flows on municipal and non-energy industrial water supplies" can be assessed. The projections are being formulated by Hanley Jenkins of DNRC.

Establishing coal and energy-related development estimates was accomplished by deriving a range of alternative futures--base, low, intermediate, and high--projected for the years 1980, 1985, and 2000. Each alternative future is disaggregated into five consuming sectors--household and commercial and industrial, electrical generation, synthetic fuels, and export.

It is necessary to locate the areas where this energy development will occur. Projected coal mines and electrical generation and gasification plants will be sited according to existing reserves of coal and according to energy companies' interests.

Increases in population and in employment opportunities will be dependent on the degree and location of energy development. Therefore, population and employment projections will be evolved based on estimates of energy development and on existing trends in the basin for industry and trade. Existing and future population figures will aid in showing the degree of population migration.

Assessing the effects of water storage and diversion on each community will be accomplished by combining present water requirements of communities and additional requirements resultant from growth. The critical flows of the Yellowstone River and its tributaries will be used to determine the effects to communities obtaining water from these sources for municipal and nonenergy industrial supplies.

### ENERGY PROJECTION PARAMETERS

It was necessary to establish several criteria before the development of the energy projections could commence. The first criteria was to determine the scope of the projections. A range of values intended to contain the lowest and highest levels of development with two alternative futures between, is presented. It is not necessary to conclude that one of the alternative futures is more likely to occur than another.

The second step was to determine the elements of coal mining and energy conversion which could occur in the Montana portion of the Yellowstone River Basin in the projected time frame. Only those coal reserves were considered that are economically strippable because of recent stringent federal legislation on underground coal mining and the economics of labor costs. More coal can be excavated in less time through strip mining which requires a minimal labor force.

The range of the nature of potential energy conversion facilities is large. This report considers only electrical generation and synthetic gasification plants. Uncertainties about technologies and economics of other types of conversion facilities make their projection unwarranted at this time.

## ALTERNATIVE FUTURES FOR ENERGY DEVELOPMENT

Four alternative futures were selected to represent the most likely range of coal- and energy-related development for the Montana portion of the Yellowstone River Basin. The base alternative future is an estimate of the minimum development which can occur based on current long-range coal contracts signed by energy-related companies. The high alternative future estimates the highest level of development possible considering resource limitations and trends in national shortages of energy. The low and intermediate alternative futures are estimates between the base and high, representing distinct differences among the alternative futures.

Table 42 is a cumulative exhibit of the alternative futures aggregated by their consuming sectors and year projected. In 1971 (actual data) the consuming sectors--household-commercial and industrial--are shown to have consumed 0.1 million short tons in the four alternative futures. This value is not projected to change significantly. In 1975, 1980, 1985, and 2000, these two consuming sectors are considered insignificant in relation to the total amount of coal consumed by the other consuming sectors.

A general overview notes coal consumption of electrical generation is minimal before 1980 when Colstrip Units 1 and 2 will be on line. The intermediate and high alternative futures for 1980 include all four Colstrip units. It can be observed that no synthetic natural gas facilities are projected before 1985 in any of the alternative futures, due to a minimum of five years required for completion of design, environmental impact assessment, and construction of such facilities.

Figure 7 is a display of the four alternative futures summarized in table 42. The number of million short tons consumed is illustrated on the vertical axis and year of development on the horizontal. This graph exhibits the range of development projected and the distinct difference among alternative futures.

Refinement of the alternative futures is continuing.

## POPULATION PROJECTIONS

The population projections currently underway should be in draft status by August 1, 1975. To date, existing population data have been collected and an outline of the development of the population and employment projections written. The outline, included here, describes the methodology which will be used.

TABLE 42. Base, low, intermediate, and high alternative futures for coal production in the Yellowstone River Basin, Montana (in million short tons)

Year	Consuming Sector	Base	Low Alternative	Intermediate Alternative	High Alternative
1971 (Actual)	Household and				
	Commercial-----	0.1	0.1	0.1	0.1
	Industrial-----	0.1	0.1	0.1	0.1
	Electrical				
	Generation-----	0.8	0.8	0.8	0.8
	Synthetic Gas-----	-	-	-	-
	Exports-----	6.1	6.1	6.1	6.1
	Total-----	7.1	7.1	7.1	7.1
1975	Household and				
	Commercial-----	insig.	insig.	insig.	insig.
	Industrial-----	insig.	insig.	insig.	insig.
	Electrical				
	Generation-----	1.2	1.2	1.2	1.2
	Synthetic Gas-----	-	-	-	-
	Exports-----	19.6	19.6	19.6	19.6
	Total-----	20.8	20.8	20.8	20.8
1980	Household and				
	Commercial-----	insig.	insig.	insig.	insig.
	Industrial-----	insig.	insig.	insig.	insig.
	Electrical				
	Generation-----	3.8	3.8	9.4	9.4
	Synthetic Gas-----	-	-	-	-
	Exports-----	41.4	41.4	41.4	41.4
	Total-----	45.2	45.2	50.8	50.8
1985	Household and				
	Commercial-----	insig.	insig.	insig.	insig.
	Industrial-----	insig.	insig.	insig.	insig.
	Electrical				
	Generation-----	3.8	5.4	9.4	11.0
	Synthetic Gas-----	-	23.0	61.0	61.0
	Exports-----	41.4	49.0	49.0	89.0
	Total-----	45.2	77.4	119.4	161.0
2000	Household and				
	Commercial-----	insig.	insig.	insig.	insig.
	Industrial-----	insig.	insig.	insig.	insig.
	Electrical				
	Generation-----	3.8	18.1	15.0	23.7
	Synthetic Gas-----	7.6	45.0	81.4	114.0
	Exports-----	41.4	68.0	167.5	259.0
	Total-----	52.8	131.1	263.9	396.7

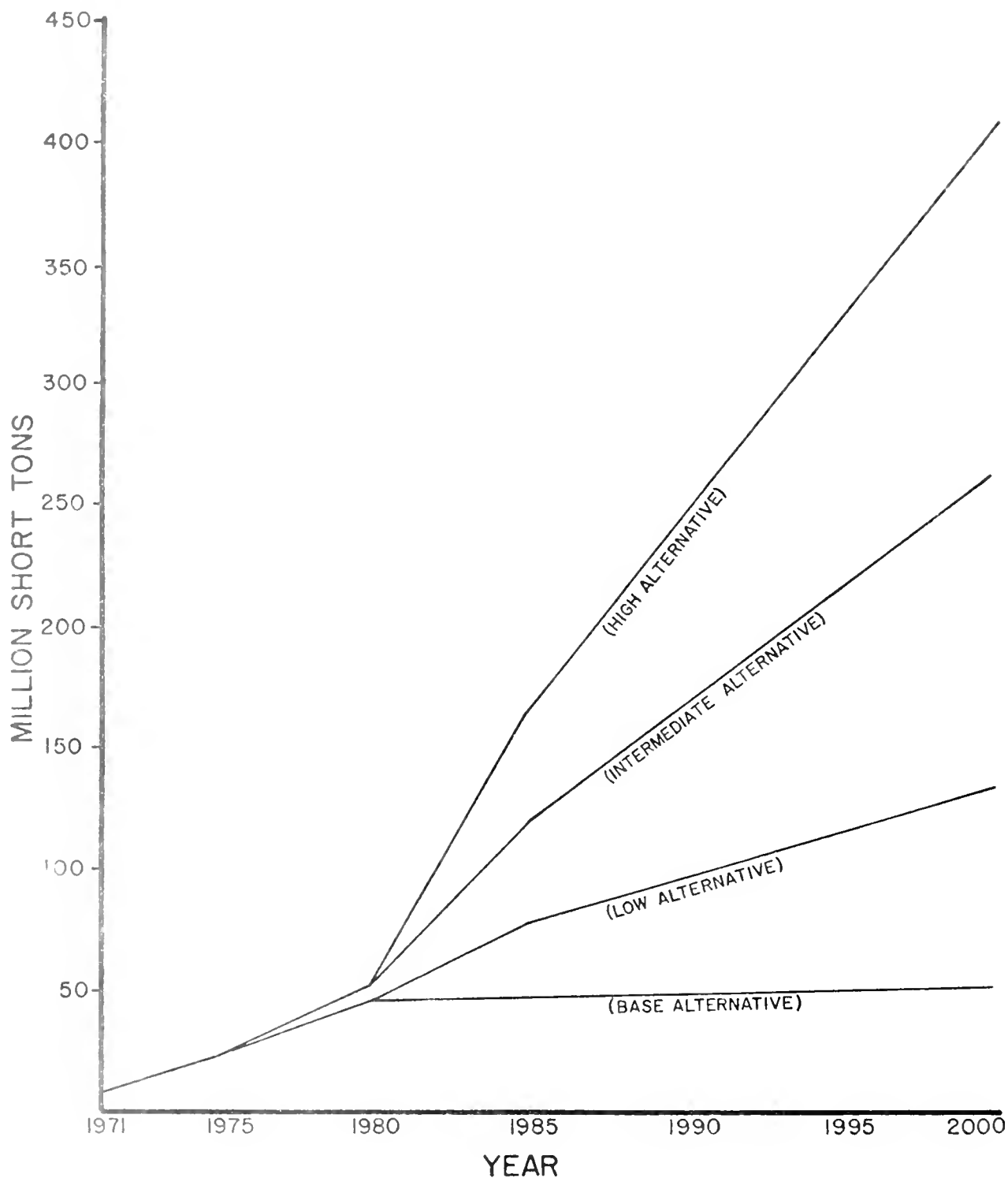


FIGURE 7. Base, low, intermediate, and high alternative futures for coal production in the Yellowstone River Basin, Montana.

## POPULATION PROJECTION<sup>M</sup> OUTLINE

### I. Existing Population Data

#### \*A. County population data by age and year

1. Apply cohort-survival model
2. Delineate existing migration rate.

#### B. Determine availability of local people for expanded future employment.

### II. Employment Demand

#### A. Basic employment estimated by energy projections

1. Operation
2. Construction

#### B. Multipliers applied to operation and construction employment.

##### \*\*1. Indirect employment

2. Employment participation rate applied to total employment
  - a. Determine 20-64 age group migration
  - b. Age distribution applied to 20-64 age group to calculate number of children. (construction and operation)

### III. Combining Existing Population Data and Employment Demand

This comparison will determine the potential population in migration due to the various levels of development.

\* Indians will have to be treated separately.

\*\* Dependent on the location and size of adjacent communications.

The development of the population projection is divided into three steps: collection of existing population data, determination of employment associated with the energy projections, and determination of total population growth. Existing county population data by age and year have been collected and will be applied to a cohort-survival model to project existing migration rates and trends in growth. Employment participation rates will be established to determine the number of people available for future employment opportunities.

The second step will be to establish basic employment demand for coal mines and energy conversion facilities estimated in the energy projection phase. Separate numbers are required for construction and operation employment. Multipliers are applied to the two working forces to determine the indirect employment, dependent on the location and size of adjacent communities that could provide the services needed for the basic employees, created by each. Estimation of the potential placement of estimated mine sites and energy conversion facilities is necessary before the potential housing situation for basic employees can be evaluated. The determination of commuting distances coupled with the number of miles people are willing to travel for services will aid in locating those communities most likely to be impacted. It should be noted that where energy development occurs on or near Indian lands, social impacts will be evaluated differently. Traditional Indian employment participation rates and fertility rates are considerably different from those in the adjacent local areas.

The third step will be to combine the existing population trends and employment requirements for future development. Migration rates for each level of energy development will be projected and the accompanying population growth estimated. Those communities projected to receive impact will be designated, and the amount of growth will be projected.

These population projections, coupled with existing water uses and sources of supply, will provide projections for future water needs for existing municipalities and selected developing communities, which in turn will aid in assessing the effects of water storage and diversion upon each community.

Task 5 is about 45% completed.

TASK 6. INVESTIGATION OF EXISTING AND POTENTIAL IMPACTS OF COAL DEVELOPMENT ON WATER QUALITY. The Grantee shall perform five subtasks:

- A) Gather and analyze water quality data for all significant surface waters in the area.
- B) Investigate water quality problems directly associated with mining and energy conversion.
- C) Investigate the adequacy of Montana's regulatory framework with respect to water pollution control.
- D) Appraise the need for additional State water quality control efforts in view of the stresses of coal development.
- E) Investigate the influences of stream dewatering on water quality.

This task is supervised by Jim Thomas of the Water Quality Bureau.

SUBTASK A. DATA

All existing water quality records for the Yellowstone River Basin in Montana were obtained from STORET. These records are being used to describe baseline water quality in various reaches of the Yellowstone River and its tributaries. For many of the smaller tributaries in the Yellowstone River Basin below Billings, very little water quality information before 1974 is available. Beginning in October, 1974, the U.S. Geological Survey began collecting monthly samples on many of these streams. Eight additional stations established by the Water Quality Bureau under this project will also be sampled monthly. In cooperation with the Fish and Game Department at Miles City, sampling sites were established on the mainstem of the Yellowstone at Hysham and below Miles City. At these sites, samples will be collected monthly in the mainstream and in the adjacent backwater. Furthermore, in order to obtain a water quality profile of the river, two water quality runs were conducted during May and June. During these runs, approximately 20 samples from the Yellowstone River, plus samples of each major tributary and some minor tributaries in the coal region, were collected and analyzed. All of the samples for a given run were collected within a two- or three-day period. To date, approximately 130 samples have been collected for analysis.

Historical water quality records of the Yellowstone Basin were analyzed to establish relationships between discharge and total dissolved solids at several stations. Using monthly averages, fairly high correlation exists between the volume of water which passes the station in a given time and the corresponding load of dissolved solids. A mass balance of total dissolved

solids was also obtained for the Yellowstone River between Billings and Sidney, again on a monthly basis. For the Yellowstone River at Billings and the Yellowstone River near Sidney, graphical relationships were obtained between the concentrations of individual ions and the total dissolved solids. Such relationships are nearly linear over a wide range of values. Additional analyses will be performed during the next fiscal year.

Water quality analyses of the Yellowstone River since 1950, shown on figures 8 and 9, indicate that no significant changes have occurred in the past 25 years. Water quality in the lower reaches, however, has probably been influenced somewhat by the construction of Yellowtail Dam and Reservoir, completed in late 1965. The Yellowstone below the Billings/Laurel area has improved as industries and cities have treated their waste discharges. The high-quality water entering the Yellowstone River in its upper reaches is gradually degraded by the time it leaves the state below Sidney. The change is from a calcium bicarbonate water in the upper reaches to a sodium sulfate water in the lower reaches. Average total dissolved solids increase from around 100 mg/l (milligrams per liter) above Livingston to 400 mg/l at Sidney, while the SAR (sodium adsorption ratio) increases from approximately 0.5 to 2.0. Total dissolved solids at Sidney may exceed 700 mg/l, partly due to the influence of tributaries in the middle and lower reaches, particularly the Clarks Fork of the Yellowstone, the Bighorn River, and the Powder River, all of which are of lower quality than the mainstream. The smaller tributaries in the coal development areas of eastern Montana are also of generally lower quality than the Yellowstone River. These streams often exhibit a high concentration of dissolved solids and a high sodium content. Because of their low volume of runoff, however, these small streams have negligible effect on the quality of the river. Downstream deterioration of the Yellowstone River is not sufficient to render the water unfit for use; it is still fairly high quality water as it leaves the state downstream of Sidney. Later in the project, the quality of each section of the Yellowstone River and its tributaries will be described according to the methods outlined in the next section.

## WATER QUALITY INDEX

In view of the hundreds of individual parameters used to measure some characteristic of a given water, it is extremely difficult to describe "water quality" in concise terms. In order to better communicate water quality information to legislators, administrators, and the lay public, the National Sanitation Foundation has developed the water quality index (WQI)--"a specific, simplistic method . . . for quantitative, consistent practice in measuring and reporting water quality" (McCelland 1974).

By definition, the WQI is a single numerical expression which reflects the composite influence of nine physical, chemical, and microbiological parameters on water quality. The parameters are given different weighting factors--determined from the judgement of water quality experts--ranging from 0.17 for dissolved oxygen to 0.08 for turbidity and total solids. The calculation of WQI is described below:

$$WQI = \frac{n}{\sum_{i=1}^n} q_i w_i$$



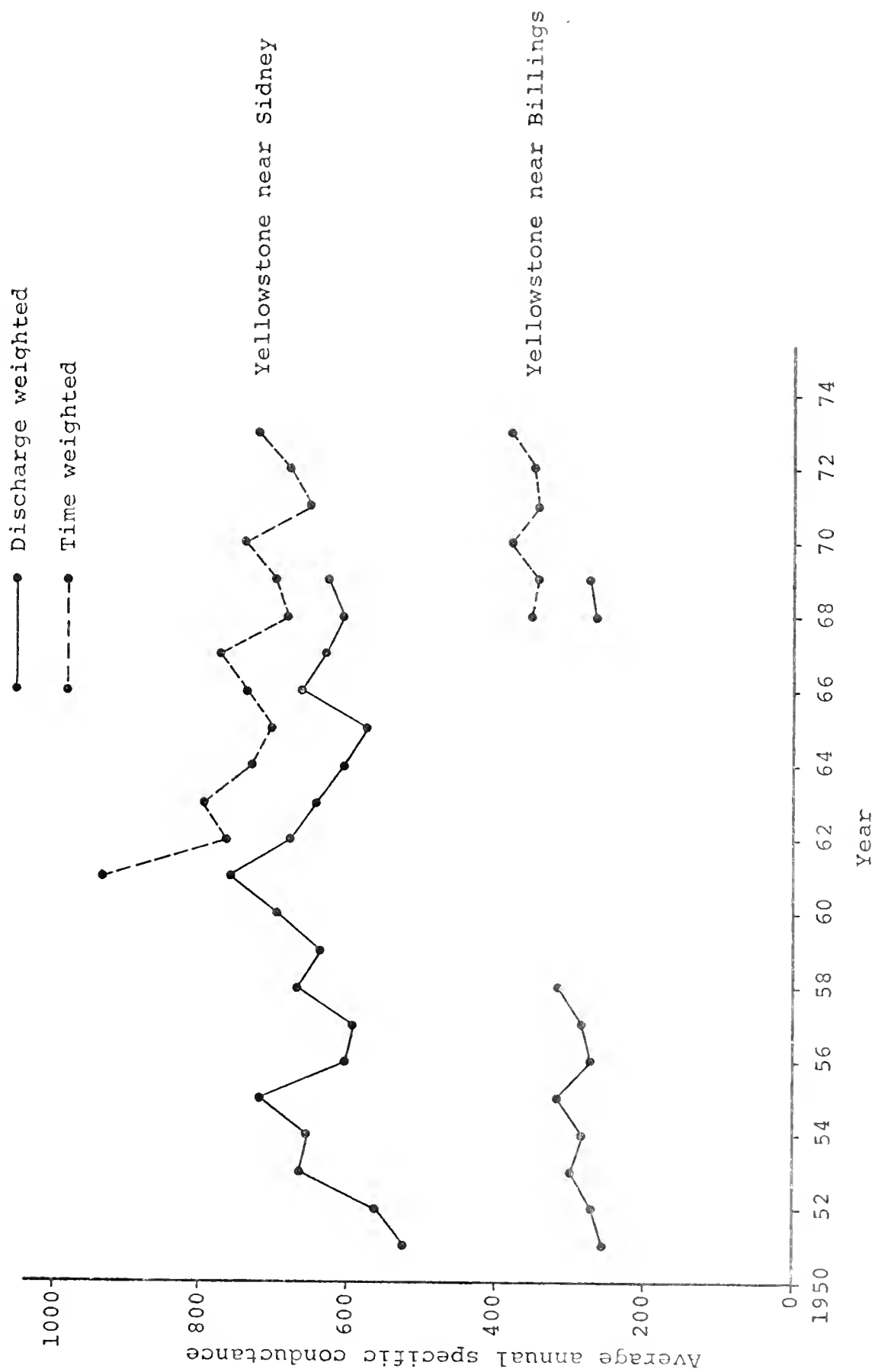


FIGURE 8. Historical specific conductance.

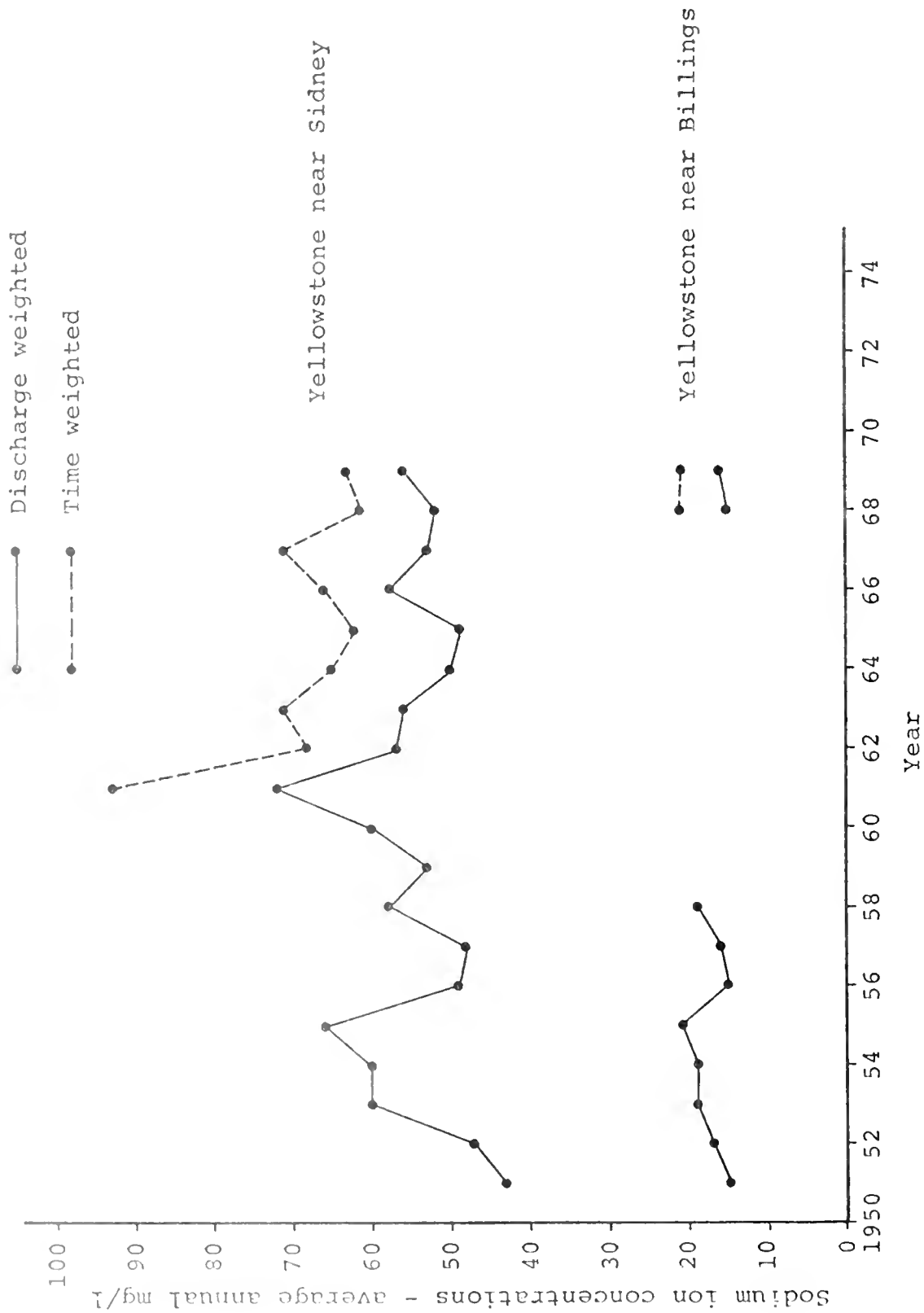


FIGURE 9. Historical Na<sup>+</sup> concentrations

where WQI = the Water Quality Index, a number between 0 and 100

$q_i$  = the quality of the  $i^{\text{th}}$  parameter, a number between 0 and 100 (read from the quality curves)

$w_i$  = the unit weight of the  $i^{\text{th}}$  parameters, a number between 0.08 and 0.17, and

$n$  = the number of parameters

In the WQI expression,  $n = 9$  and includes:

- dissolved oxygen (DO), expressed as percent saturation
- fecal coliform density (FC), no/100 ml
- pH
- nitrates ( $\text{NO}_3$ ), mg/l  $\text{NO}_3\text{-N}$
- phosphates ( $\text{PO}_4$ ), mg/l  $\text{PO}_4\text{-P}$
- 5-day biochemical oxygen demand ( $\text{BOD}_5$ ), mg/l
- temperature (T),  $^{\circ}\text{C}$  departure from natural equilibrium temperature
- total solids (TS), mg/l, and
- turbidity, JTU (Jackson turbidity units)

The resulting value for WQI will be a number between 0 and 100 with the higher values indicating a higher quality water. McCelland (1974) more fully describes the application and limitation of the WQI, and concludes that it is:

- (1) responsive to changes in water quality resulting from discharges of municipal and industrial waste effluents and agricultural runoff, and
- (2) an effective method for indicating and reporting overall quality and expressing quality trends.

The WQI, as described, is not entirely satisfactory for a relatively non-polluted stream like the Yellowstone River. It is incapable, for example, of differentiating between Water A, with SAR of 10 and TDS of 2000, and Water B, with SAR of 2 and TDS of 500. Water B, however, is much more desirable for irrigation. The WQI was designed to reflect the relative degree of commonly encountered man-caused pollution, i.e., municipal and industrial wastes. As such, it represents an important step toward improved communication between water quality experts and the general public. Where sufficient data are available, the WQI will be reported. Figure 9, for example, shows the variation in WQI and SC (specific conductance) for a water quality run on the Yellowstone River. WQI accurately records the variation in water quality, ranging from 85 (good to excellent) above Livingston to the low 50's (medium to bad) below Miles City.

#### SUBTASK B. WATER QUALITY PROBLEMS

Water quality problems associated with coal-fired energy plants, gasification plants, and strip mining have been considered thus far. Results are described below.

## POWER PLANTS

Closed-cycle, wet-cooling systems are designed to alleviate thermal pollution associated with once-through cooling. Use of these devices, however, does not entirely eliminate environmental problems. Fogging, drift, and steam plumes are common problems. In addition to cooling, water is used for several other important functions in a coal-fired power plant. Each of these functions can contribute its own characteristic waste. Sanitary wastes are not unique to power plants, so they will not be discussed. More pertinent are the wastes from 1) the condenser cooling water, 2) boiler feed water treatment operations, 3) plant system cleaning water, 4) the exhaust gas treatments system, and 5) solid waste handling system.

Potential water pollution problems are the following:

- (1) soluble toxic species
- (2) high chemical oxygen demand
- (3) excessive total dissolved solids
- (4) excessive levels of specific pollutants such as sulfate and chloride
- (5) excessive suspended solids

Wastewaters from a power plant obviously have the potential to degrade receiving waters and disrupt aquatic life. Under Montana regulations, discharges of sludge and water from sludges to receiving waters of the state generally would not be allowed. Discharges would be permitted only if the effluent equalled or exceeded natural water quality--that is, the quality of the receiving water body. It is likely that the waste would be stored in a sealed pond to prevent discharge or seepage. Barring failure of the storage pond, there should be little or no direct pollution resulting from aqueous discharges from a wet-cooled power plant.

The primary effect will be dewatering the source stream because of the water consumed through evaporation, drift, and other losses. The effects of dewatering are difficult to predict. Dewatering can increase water temperature, decrease a stream's ability to transport and assimilate waste, decrease the sediment-carrying capacity, and lower the water level. All of these effects are potentially detrimental to other beneficial uses and instream values. Attempts will be made in this study to evaluate the effects of dewatering of the Yellowstone River.

## COAL-GASIFICATION PLANTS

The technology for the production of high-Btu gas from coal is still in the developmental stage. No commercial plants are currently operating in the United States. Thus, estimates of water use and wastewater production from coal-gasification plants must be based on research and proposed designs, not operating experience. Table 43 identifies the quantity and nature of major sources of wastewater within one proposed gasification complex. Assuming zero aqueous discharge, the principal effect of a coal-gasification plant on water quality will be dewatering of the source supply, as with power plants.

TABLE 43. Quantity and nature of major wastewater streams for  $270 \times 10^6$  SCF/Day plant proposed for Wyoming

Source	Design quantity, gpm	Nature
Major Phenosolvan Effluent	2947	Rich in $\text{NH}_3$ , $\text{H}_2\text{S}$ , and low boiling organics
Minor Phenosolvan Effluent	1097	Rich in high-boiling organics, fatty acids, ammonia, coal dust, and dissolved solids
Oily Sewer	180	Oily with suspended solids
Sanitary Waste	19	Like municipal sewage
Storm and Fire	67	Oily with suspended solids
Selected Blowdowns	327	Clean with moderate dissolved solids

Source: SERNCO 1974

Ideally, both power plants and gasification plants can be designed and operated to virtually exclude direct pollution of surface and ground waters. Man's ability to produce environmental damage, however, tends to increase faster than his ability to foresee and control that damage. Large coal-fired power plants are new to Montana, and huge gasification plants are new to mankind. The potential for water pollution is obvious--blowdown, feed water chemicals, coal piles, wet sludges and ashes, trace elements, oily wastes and phenols, heated effluents, etc. Careful design can reduce the probability of pollution, but only operating experience can reveal the extent of incidental and accidental waste discharges.

## SURFACE MINING

Water pollution potentials of Montana mines may be categorized as follows:

1. Drainage water, although generally not acidic, may be highly mineralized or otherwise of poor quality.
2. The stockpiled overburden is subject to natural precipitation.
  - a. Water thus exposed to this heterogeneous material is likely to dissolve many common salts and trace elements which are carried into streams or infiltrate the ground water.
  - b. Overburden material is also prone to erosion, which can clog natural waterways and disrupt aquatic life.

3. After replacement of overburden in the pits and reshaping and revegetation of the surface, erosion and siltation should be reduced. However, the overburden material replaced will be leached by ground water and may lower water quality in the aquifer. Leached substances will move down gradient.
4. Extensive disruption of land forms in the mine area can drastically modify natural drainage patterns, causing increased erosion and sedimentation which may in turn result in higher dissolved solids in the surface water, and destroy local aquifers, causing loss or pollution of ground water.
5. Miscellaneous problems include:
  - a. disposal of sanitary waste
  - b. disposal of oil, grease, antifreeze, etc., from mining equipment
  - c. the accumulation of pollutants from blasting operations, particularly nitrogen compounds
  - d. accidental spills or discharges of pollutants

Measures are available to alleviate some of the problems listed above:

1. Water collected in the pits can be pumped to storage basins where settleable solids will be deposited. If the decantate is of sufficient quality, it can be discharged; otherwise it must be treated or stored until evaporation leaves only solids to be disposed of. Often, pit water will be utilized for dust control or irrigation of reclaimed land.
2. Diversion channels can be constructed to direct surface runoff away from the highly erodable spoil piles.
3. Sediment basins can be formed to collect internal surface runoff from spoil piles and thus prevent sediment from leaving the mine area.
4. Reclamation can be designed to retain precipitation in place to be used by vegetation, and thereby minimize surface runoff.
5. Known toxic spoil material can be buried between impervious layers or otherwise separated from contact with water.
6. Waste oil and other substances resulting from equipment maintenance can be stored in leak-proof containers for possible recycling or disposed of in such manner as to prevent water pollution.
7. Properly designed and operated septic tank systems or lagoons can be used for treatment of sanitary waste.

The toughest problem to solve may be the contamination of the ground water through the leaching of salts and toxic materials from exposed spoils. Once such substances contaminate the aquifer, attempted remedial measures may be ineffective. The ground water surrounding the mine should be monitored closely to detect such pollutants early, so that corrective measures can be undertaken.

Although local ground water pollution may occur, mining technology has advanced to the state that a well-operated surface mine should produce little or no pollution of surface waters beyond the boundaries of the mine, either during operation or after being properly reclaimed. The key element in this success is the enforcement of effective regulations governing mining and reclamation.

## INDIRECT EFFECTS

Direct water pollution from energy-conversion facilities and mining activities may be manageable--with adequate planning and design, careful operation, frequent monitoring, rigid enforcement of regulations, and a little luck. The probability of significant water pollution, however, will rise as the number of active mines and conversion facilities increases. Indirect water pollution (as well as a general deterioration of the environment) also will accompany large-scale energy development, but insufficient information is available to accurately predict these potential effects.

Indirect effects range from fogging, icing, and drift in the vicinity of cooling devices to subtle climatal changes affecting the world's weather patterns. A new microclimate, caused by the input of heat, moisture, and particulate matter from an energy-conversion facility, will exist immediately downwind of the plant. The most noticeable changes should be confined to a 2000-3000 foot radius of an individual plant. Drift from wet cooling devices containing dissolved and suspended salts will adversely affect plants, animals, and water quality within a few hundred feet of the cooling facility.

Also unknown is the fate of trace elements in coal. Part remain in the ashes (where they may contaminate local groundwater); the rest leave via the stack and are dispersed. Fallout from individual plants may be harmless, but the hazard increases with the number of plants in operation. Accumulation of toxic materials in the watershed could adversely affect water quality, particularly in lakes and reservoirs.

A major indirect effect of extensive energy development in eastern Montana will be "people pollution"--an influx of workers and their families into sparsely settled areas. Both point and nonpoint water pollution will increase from general human activity.

## SUBTASKS C AND D

To date no reportable work has been done on Subtasks C and D.

## SUBTASK E. EFFECTS OF DEWATERING

The major effect of increased development in the Yellowstone Basin, whether related to energy or increased irrigation, will be to dewater the Yellowstone River. Therefore, an understanding of the possible results of dewatering, including reducing the stream's ability to transport and assimilate waste, decreasing the sediment-carrying capacity, lowering the water level of the stream, and possibly increasing the water temperature, is imperative.

Dewatering of the Yellowstone River and its tributaries has been occurring continually since irrigators first diverted water to their lands in the late 1800's. Average annual depletions for the entire Yellowstone Basin, including Wyoming's portion, reached more than 2.5 million acre-feet per year by 1910, 3.2 million acre-feet per year by 1949, and 3.8 million acre-feet per year by 1970. In Montana alone, presently irrigated lands total about 630,000 acres and consume annually an estimated 1.5 million acre-feet of basin water (Montana DNRC 1975). Therefore, the Yellowstone River has been subjected to progressive dewatering for nearly 100 years. Unfortunately, no records exist to describe the character of the Yellowstone River before dewatering began. Substantial stream gaging was not instituted until 1929 and water quality data were not collected until around 1950. Consequently, no baseline data are available to describe the state of the Yellowstone under natural conditions. Available records indicate that relatively high quality water entering Montana from Yellowstone National Park is gradually degraded as it flows down the Yellowstone Valley and enters the Missouri River in North Dakota. Part of this deterioration is natural and part of it can be attributed to man's activities, and the amount attributable to each source cannot be determined. The additional depletions of over 600,000 acre-feet per year between 1949 and 1970 (approximately 7% of the 8.8 million acre-feet average annual flow of the Yellowstone River at Sidney) has had no obvious effect on water quality (USDI 1975). Since 1965 the effects have been obscured by releases from Yellowtail Dam which have modified the natural flow regimes and water quality in the lower Yellowstone.

Figure 8 illustrates the natural variation in specific conductance during extreme high- and low-flow years for the Yellowstone River near Sidney.

The years represented include those with the highest and lowest annual runoff since 1950. Values for the dry year (1961) are significantly higher, averaging 32% more than corresponding figures for the wet year (1965). The sodium adsorption ratio (figure 9) follows a similar pattern, averaging 27% higher during 1961. Water quality also varies widely within a given year in response to the annual cycle of snowmelt and runoff. As shown in figures 10 and 11, the concentration of dissolved solids (as measured by specific conductance) is lowest during spring runoff and highest during low-flow periods. Suspended sediment concentrations, on the other hand, are highest during spring runoff. Thus, dewatering might tend to increase the concentration of solids and reduce the concentrations of sediment. More attention will be given the subtleties of dewatering in future reports.



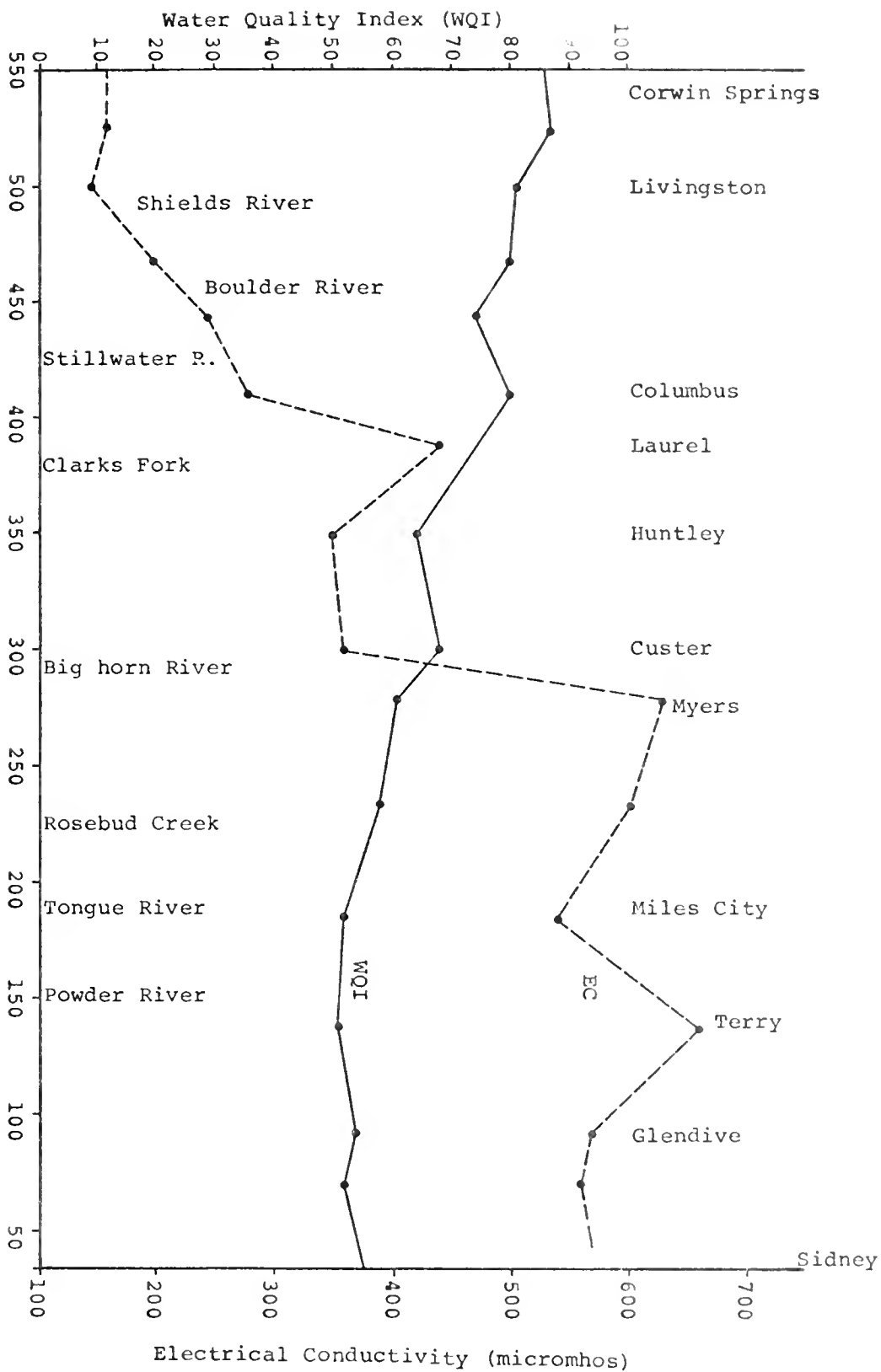


FIGURE 10. Recent water quality index & specific conductance

— 1961 (Q=5884 cfs)  
 - - 1965 (Q=17,350 cfs)

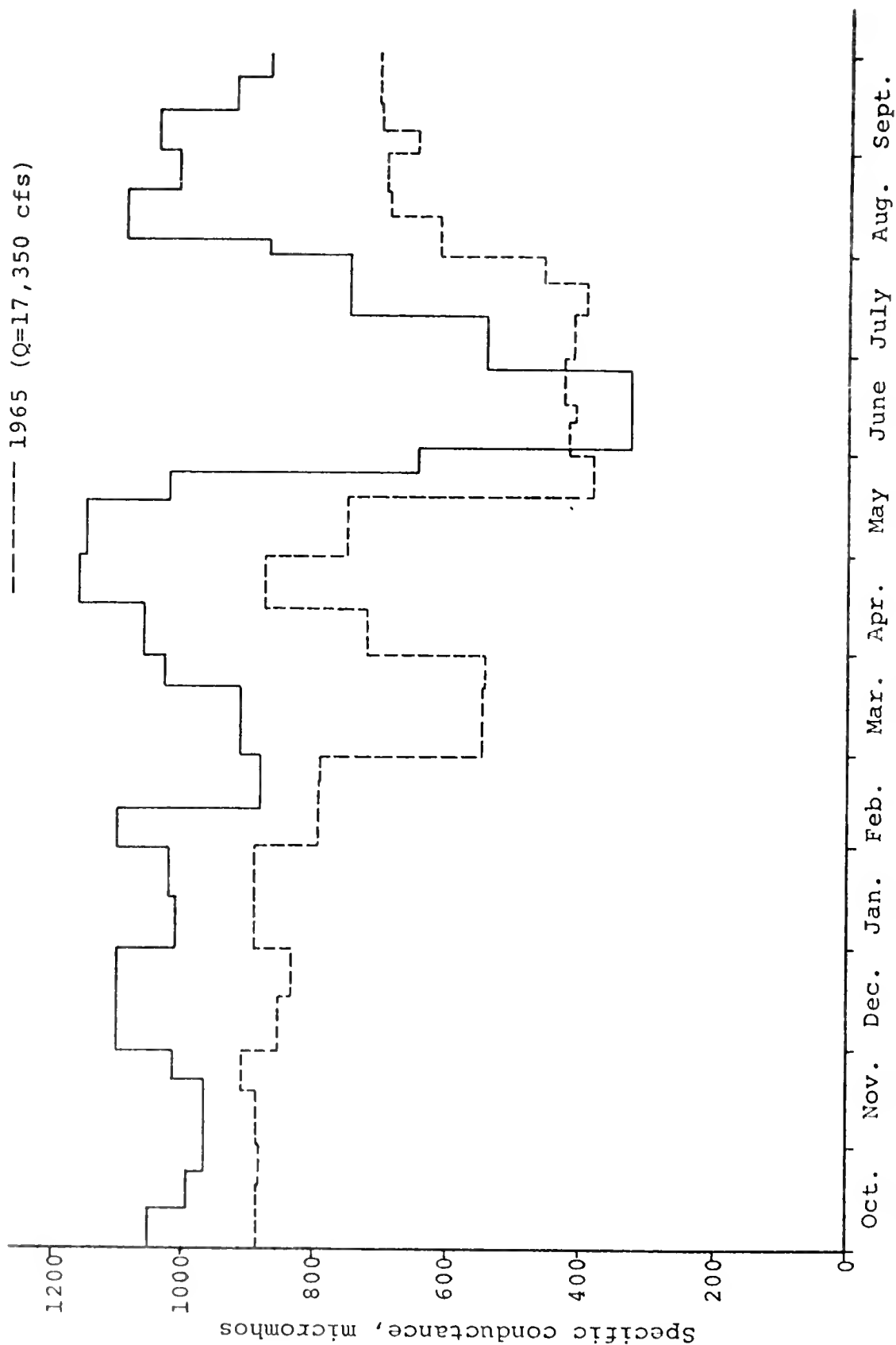


FIGURE 11. Specific conductance at Sidney, Montana: Yellowstone River

#### ACTIVITIES PLANNED FOR NEXT QUARTER

1. The sampling program will be continued to determine:
  - A. Baseline water quality.
  - B. Effects of irrigation on water quality.
2. The effects of dewatering on water quality will be investigated more thoroughly.
3. Attempts will be made to quantify or place in proper perspective the effects of many of the potential pollutants(i.e., trace elements from stack emissions, salt drift from cooling towers, nonpoint sources, erosion from mined lands, etc.) which have so far been described only qualitatively.
4. Assess the effects of various development scenarios on future water quality.
5. Identify areas of uncertainty.
6. Examine policy implications.

This task is approximately 40% completed.



TASK 7. INVESTIGATION OF WATER-BASED RECREATION ON THE YELLOWSTONE RIVER .  
The Grantee shall perform three subtasks:

- A) Compile and review current recreation usage of the Yellowstone study area in terms of volume, type, and geographic location.
- B) Assess the impact of altered stream flows on current and potential recreational uses.
- C) Conduct a field evaluation of alternative and additional recreation sites with potential for water-based recreation.

### INTRODUCTION

Max Erickson, Montana Department of Fish and Game, is performing this task. To date, most work has been directed toward compilation and review; at a later stage in the project assessment and field evaluation will be related to use. A substantial amount of literature review has been accomplished. Orientation to and reconnaissance of the study area were initiated and communication established with individuals acquainted with specific areas. Land ownership was plotted along the Yellowstone River in six of eleven Montana counties for future planning of possible alternative sites.

There are three subjects to be discussed in this report: a) the completed pilot study on recreational use, b) recreational visitation frequencies along the Yellowstone River, and c) tributary evaluation via data collection other than personal observation.

The March 31, 1975, report contains a tabulation of results of site inventory surveys taken by caretakers during the late summer of 1974. The survey documented the equipment used and recreational use of ten recreational areas in eastern Montana.

## PILOT STUDY RESULTS

A questionnaire was designed to survey people who engage in water-based recreation in the study area (figure 12). This questionnaire was designed to evaluate spring recreational use with the understanding that further refinement for summer use would be made at the completion of a small pilot study begun upon completion of the questionnaire design. The pilot study was conducted from May 5 to May 27, 1975. Questionnaires were completed by one person from each of 88 groups. Groups, defined as a number of persons who have traveled to an area together, could usually be identified easily by visual observation. A single person was considered a group, although questionnaire data indicated that he or she was alone. Within the limited time span, the main objective was to obtain as many completed questionnaires as possible. The majority (84.1 percent) of the completed questionnaires were filled out by recreationists at the Intake Fishing Access Site during the latter part of May, 1975. Other sites visited were the Twelve Mile Dam on the Tongue, the mouth of the Tongue River, the Pumpkin Creek Bridge, and the East and West Rosebud fishing access areas on the Yellowstone River near Forsyth (figure 13). Time and distance between sites, in addition to the fact that people were not using other sites in sufficient numbers, limited the scope of study.

The basic objective of the pilot study was twofold. One objective was to discover design errors, unpopular or lengthy questions that produced poor response, and/or questions obtaining useful data that should have been incorporated but were omitted. Secondly, since the sample number was to be relatively small (88 upon completion), the data proved useful in evaluation of recreational use and attitudes.

Analysis of the data, which included summations for each questions and cross tabulations to emphasize pertinent relationships, was compiled by computer at Montana State University.

The results of 88 questionnaires are listed here. If response to a question was less than 10 percent (9 people) the results will not be discussed.

Question 1. Have you noticed much a) deterioration in water quality or b) increase in litter since you started using the Yellowstone River for recreation, and c) does it affect your enjoyment of the river?

- a. There were 80 valid observations here. Of those who answered, 15 percent reported a deterioration in water quality, whereas 85 percent did not. Water quality to the interviewees was defined by the color of the water. Clean, blue water would be good quality water; murky, brownish water would not.
- b. Of 82 valid observations, 29.3 percent noted an awareness of increased litter.
- c. Of 82 valid observations, 35.4 percent indicated that either litter or deterioration in water quality had affected the enjoyment received from the river. In a survey done in southern Saskatchewan (Parkes 1974), over two-thirds of 560 recreation users indicated that they were willing

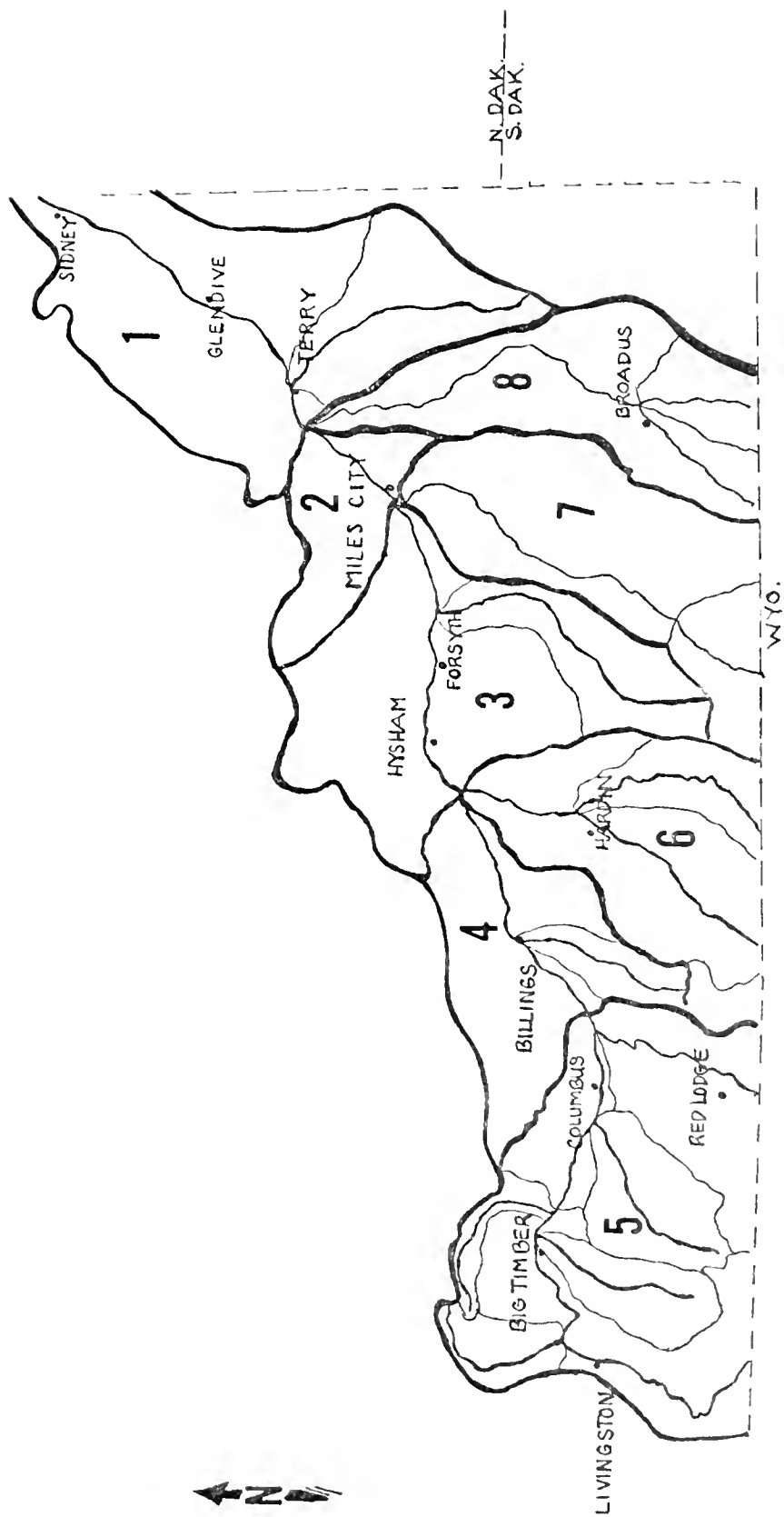


FIGURE 12. Old West Regional Commission Yellowstone study area

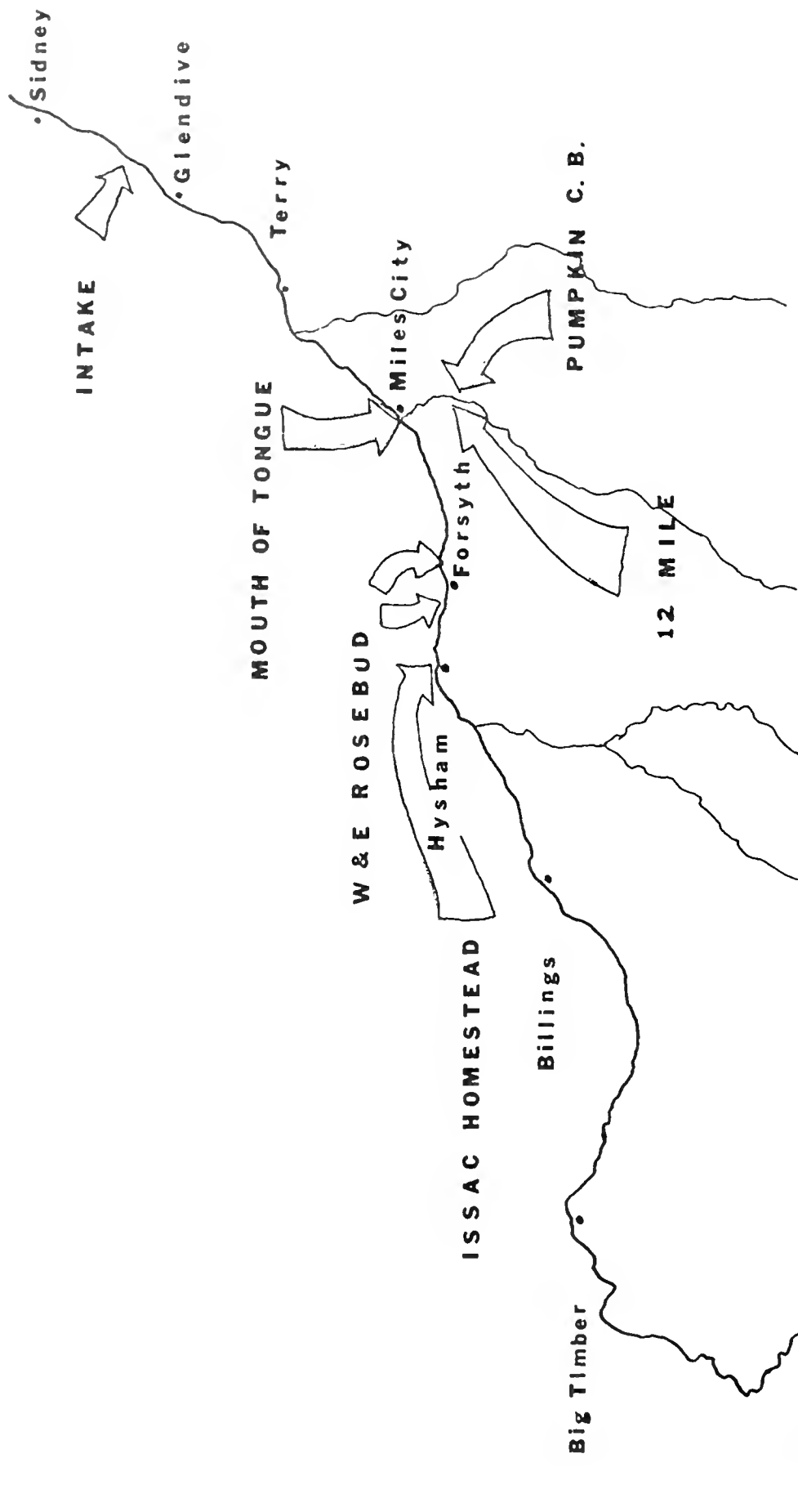


FIGURE 13. Pilot study visitation sites



to pay between 49 cents and 61 cents each per use day per season, over and above the additional expenses to which recreationists are subject, for improved water quality.

Question 2. Length of present stay. Of 83 valid observations, 53 percent were day users only, 10.8 percent stayed one night, 10.8 percent stayed two nights, 13.3 percent stayed three nights, 2.4 percent stayed six to eight nights, and 3.6 percent stayed over 10 nights.

Question 3. Please record the access and waterway you are presently enjoying. Of 88 valid observations, 84.1 percent were completed at Intake Fishing Access, 11.4 percent at East Rosebud Fishing Access, 1.1 percent at the Twelve Mile Dam on the Tongue River, 2.3 percent at the mouth of the Tongue, and 1.1 percent at the Pumpkin Creek Bridge near Twelve Mile Dam.

Question 4. a) Are you presently on your vacation? Of 85 valid responses, 16.5 percent were on vacation, while 83.5 percent were not.

b) Was recreation on the Yellowstone River and/or tributaries the primary purpose of your trip? Of 75 valid observations, 69.3 percent replied that recreation on the Yellowstone River was the primary purpose for the trip.

c) If no, what is the main reason for your trip? Of the 23 people who replied "no" to the previous question only one non-response was received. Although the question was open ended, the purposes fell into the following categories: 1) visiting relatives and/or friends, 27.3 percent, 2) sightseeing, 9.1 percent, 3) enjoyment and/or rest and relaxation, 9.1 percent, 4) business- or work-related activities, 13.6 percent. Interpretation of the question apparently presented problems to some, as indicated by the large percentage (31.8 percent) who replied "fishing."

Question 5. How often do you visit this particular site each year? (spring, summer, fall and winter?)

a) Spring. Of 84 valid responses, 17.9 percent indicated that presently they were at this site for the first time ever, 15.5 percent replied they visited the area once each spring, 20.2 percent said two to three times, 9.5 percent said four to six times, 4.8 percent said six to eight times, and 32.1 percent said over eight times each spring.

b) Summer. Of 45 valid observations, 22.2 percent visited the area once each summer, 20 percent visited two to three times, 6.7 percent visited four to six times, 2.2 percent visited seven to eight times, and 48.9 percent visited over eight times.

c) Fall. Of 17 valid observations, 41.2 percent indicated that visitation occurred over eight times each fall season.

d) Winter. Only seven valid responses were received, indicating relatively light winter recreational use.

Question 6. Yearly, how many days do you spend enjoying recreational activities at other sites on the Yellowstone River and/or its tributaries? Of 73 valid responses, 49.3 percent indicated from one to nine days; 16.4 percent indicated from ten to fifteen days; 5.5 percent indicated from 16 to 20 days; and 28.8 percent indicated over 20 days of use.

Question 7. Please mark (x) the activities you have engaged in or plan to engage in while in the immediate area, as well as the number of hours spent doing each. A note must be made that, in this question, a nonresponse was considered a definite "no" rather than a missing observation.

a) Picnicking. Of 46 valid observations, 47.7 percent indicated that they did not picnic while in the area; for those who did, the most common length of picnic was two hours.

b) Swimming. There were 14 valid observations. Eighty-four percent indicated that they did not engage in swimming. The hourly data were not considered valid, due to poor response.

c) Rest and relaxation. Forty-three(48.9 percent) valid observations were received. A personal observation must be made here that rest and relaxation entails no definite outdoor recreational activity such as fishing, picnicking, etc. Rest and relaxation can be closely related with sightseeing, but generally is defined as enjoying an area with no specific purpose in mind.

d) Boating--motorized. Of the 88 valid observations, 15.9 percent indicated that motorized boating had been engaged in. The hourly data was deemed not valid, due to poor response.

e, f, g, h, i, j) Boating--non motorized river floating, horseback riding, bicycling, motor biking, driving for pleasure, and playing outdoor games: all had poor response, and the data were thrown out. During the spring season at the sites surveyed, only light use, if any, was apparent.

k) Rock hounding. Of 88 valid observations, 17.0 percent replied that they had engaged in rock hounding. Of those who replied, a two-to-three-hour rock hunt was most popular (45.5 percent).

l) Sightseeing. Of 88 valid responses, 17.0 percent replied that they had actually engaged in sightseeing. Of those who replied, 77.7 percent indicated a two-to-five-hour sightseeing duration. From personal communication, people who were visiting the area for the first time were most likely to consider themselves sightseers; 17.9 percent of 88 valid observations were visiting the surveyed site for the first time.

m) Walking for pleasure. Of 88 valid responses, 15.9 percent indicated participation in walking for pleasure; the hourly data were deemed invalid.

n) Water-skiing. The data were not valid.

o) Bird watching. The data were not valid.

r) Fishing. Of 88 valid responses, 75 percent engaged in fishing. Of those who replied, a two-to-five-hour time span comprised 21.7 percent of the durations of fishing.

1. For which species in particular? Of the 63 valid observations, 84.1 percent indicated that paddlefish were sought. Note that 84.1 percent of the 88 questionnaires were completed at Intake Fishing Access, where paddlefishing is the major attraction.
2. Which species, if any, did you catch? Of the 33 valid responses, 75.8 percent replied they had caught paddlefish.
3. How many of each species? Of the 20 responses, 50 percent replied that two paddlefish, the daily limit, had been caught.
4. What is your favorite activity or activities of this site? Of 65 valid responses, 84.6 percent replied fishing was the favorite activity.

Question 8. How does this particular site fulfill your recreational demands? Of 83 valid responses, 22.9 percent replied completely; 67.5 percent responded adequately; and 9.6 percent responded not adequately or poorly.

b) If "not adequately" or "poorly," why? Of ten valid observations, 50 percent replied the area was too crowded.

Question 9. a) Where would you go to participate in the same activities if this site was not available? Of 54 valid observations, 20.4 percent replied Fort Peck Reservoir. See table 44 for other responses.

b) Do you like that site as well as this one? Of 45 valid responses, 66.7 percent indicated that they like their second choice as well as the site they were presently using; 33.3 percent indicated that they did not. Again, from personal communication, people indicated that in many cases a second choice site was enjoyed as much, even more, than the present area, but time, money and/or distance presented problems.

Question 10. a) Do you think this site presently is too crowded, not used enough, or just right? Of 84 valid observations, 60.7 percent thought the site was too crowded, 2.4 percent thought the area was not used enough, and 36.9 percent thought the area was just right.

b) If you think this area is too crowded would you most prefer more sites available? Of 63 valid responses, 83.3 percent indicated that they would, whereas 12.7 percent indicated that they would not.

c) If "yes" within how many miles upstream or downstream would you like to see at least one more site? Of 40 valid responses, 17.5 percent replied within one mile, 15 percent replied one to two miles, 15 percent replied three to five miles, 17.5 percent replied six to ten miles, 10 percent replied from 11 to 20 miles, 22.5 percent replied from 20 to 50 miles, and 2.5 percent replied over 50 miles.

TABLE 44. Where would you go to participate in the same activities if this site was not available?

ALTERNATIVE SITE	NUMBER OF RESPONSES	PERCENT OF 54 RESPONSES
Twelve Mile Dam	1	1.9
East Rosebud	1	1.9
Don't Know	1	1.9
Yellowtail	2	3.7
Ft. Peck	11	20.4
Stay Home	5	9.3
Spotted Eagle	3	5.6
Yellowstone River	6	11.1
Powder River	2	3.7
Fred Robinson	10	18.5
North Dakota	3	5.6
South Side Intake	2	3.7
South Dakota	1	1.9
Fairview	1	1.9
Gartside	1	1.9
Other	4	7.5
TOTALS	54	100

d) Should this site be more fully developed? Of 78 valid responses, 66.7 percent thought the site should be more fully developed, whereas 33.3 percent thought the site should not.

Question 11. a) Has the increasing cost of gasoline decreased the distance you will travel to enjoy a recreational area? Of 83 valid observations, 60.2 percent indicated that it had not.

b) If "yes," a typical year's recreational trip covered approximately (1) miles, while this year's trip covered only (2) miles round trip.

1) Of 23 valid observations, 47.8 percent indicated trips of over 450 miles; 17.4 percent indicated trips from 0-50 miles.

2) Of 22 valid observations, 22.7 percent indicated trips of over 450 miles, whereas 45.5 percent indicated trips of 50 miles or less. Thus, of a sample number differing by only one, the percentage of people taking trips of over 450 miles in previous years decreased by 25.1 percent when compared to 1975. The percentage of trips covering from 0-50 miles in previous years had consequently increased 28.1 percent for 1975.

c) Per person, how much will your trip cost per day? Of 55 valid responses, 21.8 percent replied \$0-5, 20 percent replied from \$6-10, 12.7 percent replied from \$11-15, 20 percent replied from \$16-20, 10.9 percent replied from \$21-25, 1.8 percent replied from \$26-35, and 12.7 percent replied over \$35.

Question 12. Please check the items of equipment you have with you. Of 88 valid responses, 14.8 percent had boats (there were no canoes), 2.3 percent had water skis, 78.4 percent had fishing gear, 42 percent had cars, 44.2 percent had pickups, 27.3 percent had pickups with campers, 12.5 percent had camp trailers, 5.7 percent had motor homes, 8.0 percent had tents, 5.7 percent had motor bikes, 2.3 percent had bicycles, 5.7 percent had hiking gear, and 34.1 percent had sleeping bags.

Question 13.

TABLE 45. Age and sex of people in each of 88 groups.

SEX	YEARS OF AGE				
	1-12	13-18	19-30	31-50	50+
MALE	47	33	61	41	24
FEMALE	23	14	25	23	13

b) Are you and your group residents of Montana? Of 77 valid observations, 77.9 percent were residents of Montana.

c) If "yes" which town and county? Of 56 valid observations (the towns were not considered for the pilot study) the six most common counties of residence were: Dawson-37.5 percent, Rosebud-12.5 percent, Richland-10.7 percent, Yellowstone-8.9 percent, and Sheridan and Custer-7.1 percent each.

d) If "no", which town, county, and state? Of 15 valid responses, one (6.7 percent) was from Washington, five (33.3 percent) were from Wyoming, eight (53.3 percent) were from North Dakota, and one (6.7 percent) was from Canada.

Questions 14. Indicate which broad income category your household fits into. Of 78 valid observations, 5.1 percent indicated under \$4,999; 9.0 percent indicated from \$5,000 to \$7,999; 32.1 percent indicated from \$8,000 to \$11,999; 26.9 percent indicated from \$12,000 to \$15,999; and 26.9 percent indicated over \$16,000.

Question 15. What is a) your occupation, and b) if married, your spouse's occupation? See Table 46.

TABLE 46. Occupational categories of interviewees and spouse.

Occupational Category	Interviewee Occupation % of 85 Valid Observations	Spouse Occupation, % of 46 Valid Observations
Professional	9.4	15.4
Student	5.9	4.3
Housewife	4.7	54.3
Self-employed white collar	2.4	6.5
Self-employed blue collar	2.4	0
Employed white collar	10.6	6.5
Employed blue collar	49.4	8.7
Agriculture	10.6	4.3
Retired	4.7	0

The most common occupation (49.4 percent) among those interviewed was blue-collar work in which the interviewee had no ownership of his employer's company or holdings. The most common occupation for the spouse was housewife (5.3 percent).

Question 16. a) Are insects a problem to you in this area? Of 80 valid observations, 31.3 percent said "yes."

b) If "yes," have they reduced the time you spend enjoying your favorite activities? Of 30 valid observations, 36.7 percent responded "yes."

c) Would you return to this area if the insect problem remains the same? Of 88 valid observations, 71.6 percent indicated that they would return.

d) Would you return to this area if the insect population was reduced by at least one-fourth? Of 88 valid observations, 60.2 percent indicated that they would return.

Question 17. a) Are you aware of the location of public (Bureau of Land Management) lands near (50 miles upstream and 50 miles downstream) this area? Of 78 valid observations, 34.6 percent replied "yes" and 65.4 percent replied "no."

b) Are you aware of the location of public lands near your home if this area is not near your home (50 miles in any direction). Of 70 valid observations, 61.4 percent responded "yes" and 38.6 percent responded "no."

c) Are you aware that literature is available at any Bureau of Land Management Office providing information and location of these areas, free of charge? Of 76 valid observations, 64.5 percent responded "yes" and 35.5 percent responded "no."

d) Within the past year, have you used any of these areas adjacent to the Yellowstone River for recreational purposes? Of 75 valid observations, 52 percent responded "yes" and 48 percent responded "no."

e) If "yes" for what main activity? Of 32 valid observations, fishing was the most popular with 68.8 percent.

Question 18. What other kinds of recreation would you like to see at this particular site? Of 11 valid observations, activities and equipment for children were most asked for with 36.4 percent.

#### CROSS-TABULATIONS

The second aspect of the pilot study entails use of cross tabulations to establish certain pertinent relationships. Only those tabulations thought to be most important and valid are included here.

CT-1. Of 74 valid observations, 58.1 percent indicated that recreation on the Yellowstone was the primary purpose for their trip, but were not on their vacation.

CT-2. Of 75 responses, 65.4 percent indicated that no decrease in water quality had been noted and that the enjoyment one can derive from the site had not been affected.

CT-3. Of 76 responses, 59.5 percent indicated that no increase in litter had been noted and that the enjoyment potential of the site had not been affected.

CT-4. Of 21 valid observations, 42.9 percent indicated that Montana residents traveled 50 miles or less (round trip) on a typical recreational outing.

CT-5. Of 75 valid observations, 49.3 percent indicated that insects were not a problem in the area and that the site adequately met all recreational needs.

CT-6. Of 62 valid observations, 66.1 percent indicated that the site was too crowded, yet met the desired recreational needs adequately.

CT-7. Of 73 valid observations, Montana residents indicated that the increasing cost of gasoline had (34.2 percent) and had not (42.5 percent) reduced the distance they would drive on a typical recreation outing. Non-residents indicated 5.5 percent and 17.8 percent, respectively. An interesting note here is that if the price of gasoline was to rise to 75¢ a gallon, the additional cost for gasoline

(from 40¢ a gallon) would amount to \$35.00, 19.8 percent of the total vacation cost, assuming a family of four on a 1500-mile round trip in a car averaging 15 miles/gallon for nine days (McCool et al. 1974). Thus, recreational use in terms of activities and places of visitation could change in the future, depending upon the nation's economy.

CT-8. Of 74 valid observations, 58.1 percent of all households reported that the increasing cost of gasoline had not decreased the distance of travel undertaken for recreational outings. This included all income categories.

CT-9. Of 76 valid observations, 42.1 percent indicated a desire for more site development and, in addition, reported that the increasing cost of gasoline had no effect upon the distance traveled for a recreational outing.

CT-10. Of 78 valid observations, 34.3 percent of households surveyed indicated an income of \$8,000 to \$11,999. Of these, 24.3 percent were Montana households and 10 percent were not.

CT-11. Of 23 valid observations, 52.2 percent reported that fishing was the most preferred activity and that fishing was the main activity on public land.

CT-12. Of 60 valid observations, 61.7 percent indicated that insects were not a problem presently, but could prevent a return trip if in sufficient numbers.

The schedule of visitation for the summer survey starting June 22 was formulated. This survey again uses a questionnaire, but one which has been redesigned due to mistakes and problems that arose from the pilot study questionnaire.

## VISITATION FREQUENCIES

The second major aspect of data gathering entailed recreational visitation frequencies along the Yellowstone River. Evaluation of use was accomplished through automobile and airplane trips along the Yellowstone River as well as recreational use observations made by personnel of the Montana Department of Fish and Game while working on the river. For each trip, the date and the section of river traveled was noted. Thus, one may document where people do not use the river as well as where they do. A note is made here that observations from automobiles cannot encompass all portions of the river due to limited accessibility, whereas observations from the air are virtually complete.

Along the Yellowstone River, there are five sub-major drainage basins considered here (figure 12--heaviest lines). Since these drainage basins are geographically workable units, data have been documented within each sub-major drainage basin along the river, which will be called "sections."

Section 1. (See figure 14). From the Montana-North Dakota state line there are 149.5 river miles to the mouth of the Powder River, which is not included in Section 1. The largest town within this section is Glendive, the second largest, Sidney. Generally speaking, popular recreational areas along the river within each section occur at nearly every small community along the river due to some convenient access. In addition, the mouths of Cabin Creek, O'Fallon Creek, and Cedar





FIGURE 14. Yellowstone River Section 1.

TABLE 47. Observed recreational use by activity in Section 1.

	Terry Bridge		Fallon Bridge		Glen- dive		Intake	Total
TOTAL OBSERVATIONS	10	11	10		11	11	9	
Fishermen	11	11	0		32	0	1023	1077
Rockhounds	0	2	0		0	2	0	4
Sightseers	0	0	0		0	0	2	2
Fish and Boating	0	0	0		0	3	0	3
Canoeists	0	0	0		0	3	0	3
Rest and Relaxation	0	0	0		3	0	53	56

Creek receive notable use at various times of the year, usually fishing (Stor-dahl personal communication). Within this section lies Intake Fishing Access which is extremely popular from approximately May 1 to July 1 of each year for paddlefish fishermen and their families. Use data are shown in table 47. These data, as in all sections, were compiled from March 1 to June 17, 1975, at varying intervals.

Section 2. (See figure 15). From the mouth of the Powder River, which is included in Section 2, to the mouth of the Tongue River, which is not, there are 35.5 river miles. The mouth of the Powder River, the mouth of Cottonwood Creek, the mouth of Sunday Creek, and areas of convenient access near Miles City east of the mouth of the Tongue River all receive substantial use. Documented data appear in table 48.

Section 3. (See figure 16). From the mouth of the Tongue River at Miles City, which is included in Section 3, to the mouth of the Bighorn River, which is not, there are 110.6 river miles. This section includes East and West Rosebud fishing access areas near Forsyth and a relatively popular access at Myers, just west of Hysham. Also included within this section is the Isaac Homestead Game Management area, in which extensive data (DeSimone personal communication) has been collected and will be discussed separately. (tables 49 and 54).

Section 4. (See figure 17). From the mouth of the Bighorn River, which is included in Section 4, to the mouth of the Clarks Fork of the Yellowstone, which is not, there are 83.6 river miles. Within this section lie many access points for recreation, the most notable at or near Custer, Pompey's Pillar, Huntley, Waco Diversion, and the city of Billings (table 50).

Section 5. (See figure 18). From the mouth of the Clarks Fork, which is included in Section 5, to the mouth of the Boulder River at Big Timber, there are 76.8 river miles. Included within this section are access points at the town of Laurel, Itch-Kep-pe at Columbus, Indian Fort at Reed Point, the relatively unused Brattin Fishing Access, just east of Reedpoint, and the town of Big Timber (table 51).

Within each of those sections, use has been documented in the respective tables, not only at the mentioned popular recreational places, but areas between. This accounts for the data not listed directly under the column headings.

## SPECIFIC INFORMATION

More extensive data has been compiled at the Intake Fishing Access within Section 1, to emphasize the high recreational use there. Maximum numbers occurred on May 26 and May 28 of 1973 and 1974, respectively. Both dates fell on the Memorial Day weekends. The high concentrations of fishermen on the two Memorial Day weekends and the low daily fishing success known to have occurred on this holiday in 1974 (0.198 fish per hour), suggest angler concentrations are the result of custom and available time, not high fishing success. The estimated number of fisherman trips (May 1 to July 1) was 2,386 in 1975 and 3,363 for 1973 and 1974 (Rehwinkel 1975). From May 1 to June 3 of 1975, a counter rod registered 3,384 units depicting another use increase. In addition, tables 52 and 53 depict

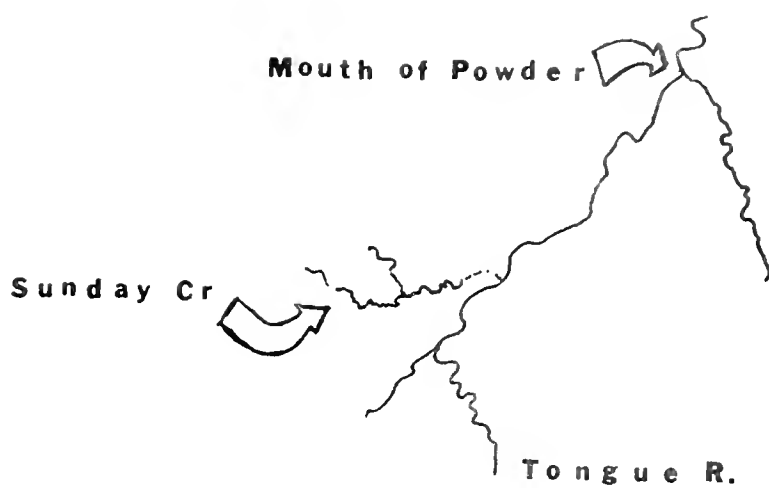


FIGURE 15. Yellowstone River Section 2.

TABLE 48. Observed recreational use by activity in Section 2.

	Mouth of Powder	Total
TOTAL OBSERVATIONS	12	
Fishermen	2	2
Rockhounds	2	2
Sightseers	3	3
Fish and Boating	0	0
Canoeists	0	0
Rest and Relaxation	0	0

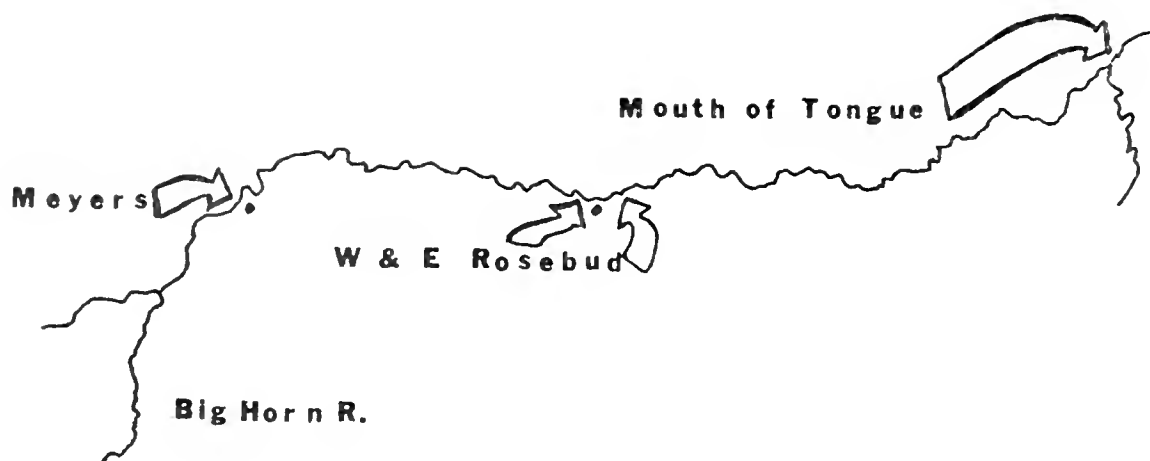


FIGURE 16. Yellowstone River Section 3.

TABLE 49. Observed recreational use by activity in Section 3.

	Myers	W. Rosebud	E. Rosebud	Mouth of Tongue				Total
TOTAL OBSERVATIONS	13	13	13	13	13	30	15	
Fishermen	2	23	6	82	12	64	9	198
Rockhounds	0	9	1	0	9	2	0	21
Sightseers	0	0	0	0	0	0	0	0
Fish and Boating	0	0	0	0	0	0	0	0
Canoeists	0	0	0	0	0	0	0	0
Rest and Relaxation	4	13	3	0	0	0	2	22

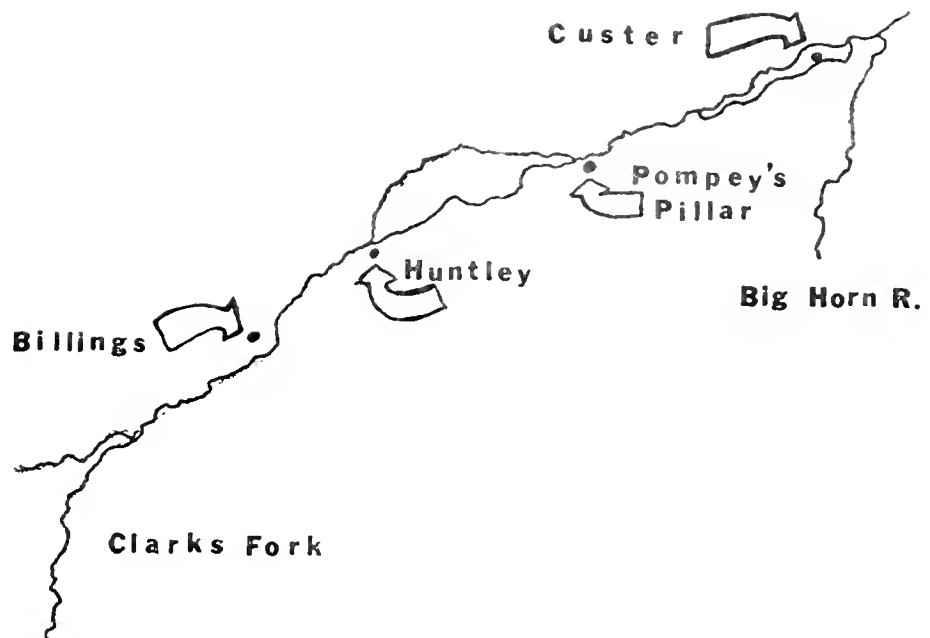


FIGURE 17. Yellowstone River Section 4.

TABLE 50. Observed recreational use by activity in Section 4.

	Billings	Huntley	Pompey's Pillar	Custer		Total
TOTAL OBSERVATIONS	7	6	6	7	7	
Fishermen	0	3	0	0	0	8
Rockhounds	0	0	0	0	0	0
Sightseers	0	0	0	0	0	0
Fish and Boating	0	0	0	0	0	0
Canoeists	0	0	0	0	0	0
Rest and Relaxation	0	2	0	0	10	12

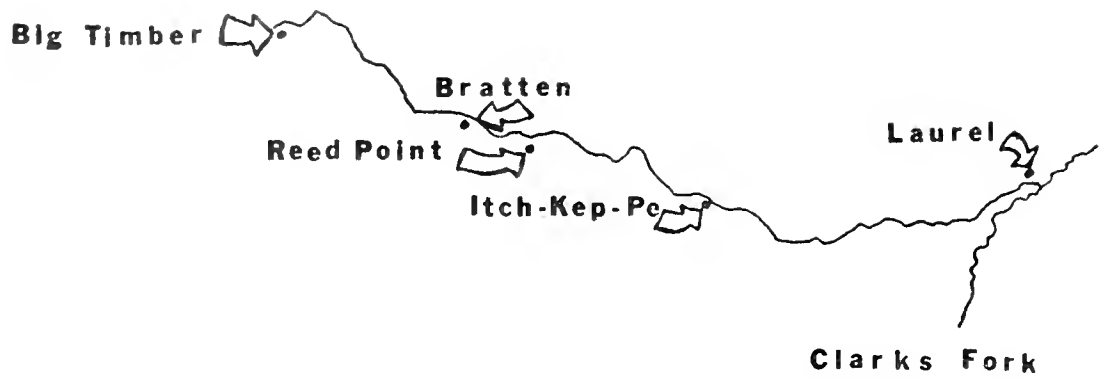


FIGURE 18. Yellowstone River Section 5.

TABLE 51. Observed recreational use by activity in Section 5.

	Big Timber	Bratten	Reed Pt.	Itch-Ke-Pe	Laurel	Total
TOTAL OBSERVATIONS	2	2	2	2	3	7
Fishermen	0	0	2	3	2	7
Rockhounds	0	0	0	0	0	0
Sightseers	0	0	0	0	0	0
Fish and Boating	0	0	0	0	0	0
Canoeists	0	0	0	0	0	0
Rest and Relaxation	0	0	0	4	0	4

TABLE 52. Fisherman residence as determined from warden creel checks.

May	1st week	2nd week	3rd week	4th week	June 1st week	2nd week
Baker	2	3		8	2	1
Biddle						1
Big Timber					1	
Billings	1	3	4			5
Butte					3	
Colstrip					1	3
Culbertson					1	
Deer Lodge	4					
Ekalaka				3		
Enid						1
Fairview					1	
Glasgow				3		
Glendive	26	53	17	16	7	19
Helena		1				
Hlysham					3	
Intake						3
Livingston					1	
Mandan		1				
Meitown						5
Miles City	10	1	6	13	2	6
Plentywood					3	
Plevna						1
Poplar					2	
Richey					2	
Roundup					1	
Savage		2				
Sidney	7	1	3		2	2
Terry					3	1
Townsend			1			
Willard		1				
Wolfpoint	1				2	
California					1	
Colorado				7	3	1
No. Dakota	4	8	4	6	2	17
So. Dakota	1					
Idaho				5		
Illinois						1
Iowa						4
Kansas	1				1	1
Minnesota					1	1
Oklahoma		1				
Wyoming	2		7	1	15	8

TABLE 53. Fisherman use at Intake during spring, 1975

MAY	NUMBER FISHERMEN	TOTAL HOURS FISHED	NUMBER FISH CAUGHT
1st week*	59	143.20	0
2nd week	75	256.25	25
3rd week	42	162.00	29
4th week	62	287.00	26
JUNE			
1st week	62	363.25	54
2nd week	81	315.50	112

\* 1st week: May 1, 2, 3, 4; 2nd week: May 8, 9, 10, 11, 13, 14; 3rd week May 15, 16, 17; 4th week: May 22, 23, 25, 29. June- 1st week: 1, 2, 3; 2nd week June 11, 12.



a subsampling technique (Elser personal communication) used to determine representative total hours fished, number of fish caught, and residency. Glendive residents comprised the largest percentage of the population.

Another area of interest is the Isaac Homestead Game Management Area, located near Myers. This 1200-acre tract of land is becoming extremely popular, not only for hunting, fishing, and camping, but for seasonal recreational uses such as asparagus picking (table 54).

Also, ling fishing has become an extremely popular recreational activity at the East Rosebud Fishing Access Site on the Yellowstone River (figure 13). From a selected subsample (Haddix personal communication) 36 fishermen fished 38.25 hours from February 19 to March 19, 1975. There were 251 burbot taken, a 2.57 average catch per angler hour. From March 1 to June 17, 1975, on 18 observations, there were 82 fishermen and 16 people resting and relaxing. Since most observations (13) were not made at night, when ling fishing success is at its best, these figures should be considered extremely low. The convenient access and high rate of fishing success greatly appeals to many people, mostly from Forsyth, Miles City and Colstrip.

Boating information, to date, has been limited to Custer County. There are 147 registered boats in Custer County, of which 85.7 percent are outboards, 9.5 percent are inboard-outboards, 2.7 percent are jet boats, and 2.1 percent are classified as "other." From personal communication, it is known that only jet boats are consistently used on the Yellowstone. During periods of high water, outboards and inboard-outboards are used to some extent, especially by persons knowledgeable of the river channels. During the fall, notable use is also received due to the relative clearness of the water, which allows sandbars and debris to be avoided.

#### TRIBUTARY RECREATIONAL USE

The methodology for tributary evaluation has, to date, been dependent upon literature review, personal communication, and game warden creel census checks, which have been tabulated for 1966, 1967, 1968, and a portion of 1975. In addition, during 1973 a grand total of 18,648 fisherman days and 138.1 fishermen per day were noted on the Bighorn River below Yellowtail Dam (Stevenson 1975).

#### DISCUSSION AND CONCLUSIONS

The pilot study results will not be discussed in detail. The sample number of 88 is not considered large enough to draw conclusions relating to recreational use within the study area. Also, as in most questionnaires, errors can be expected with certain questions due to interviewees who did not reply to all segments of each question. Missing observations and nonresponses do not always equate, because of the question structure.

From data thus far collected, only a limited number of valid statements can be made. The first, and most obvious, is that the Intake Fishing Access area has received a tremendous amount of recreational activity from May 1 to July 1 during 1973, 1974, and 1975 (Rehwinkel 1975, Elser personal communication). The popularity

TABLE 54. Recreational use of Isaac Homestead from June 20, 1974 to June 8, 1975.\*

USES	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MARCH	APRIL	MAY	JUNE	TOTAL (YR)
Fishing	4-18	8-77	18-42	5-34	19-77	4-6		7-10.5	9-18.5	13-42	6-30.5	93-355.5
Deer Hunting				31-435	135-549.5	95-138						261-1122.5
Pheasant Hunting					56-98.5	52-76						108-174.5
Coon Hunting					30-34	27-35	15-20	2-3				74-92
Goose Hunting					13-13.5	8-5						21-18.5
Duck Hunting					24-34	2-5						26-39
Camping	4-18	7-72	3-24	2-24	2-36				8-30	11-40	2-24	39-268
Trapping					2-4	2-48	2-48	8-11				14-111
Other (Asparagus picking, bird-watching, agate hunting)	4-3	5-13	4-5	11-28	13-9.5				15-84	67-80.5	12-9	131-231
TOTAL FOR MONTH	12-39	20-162	25-71	49-521	294-856	190-313	17-68	17-24.5	32-132.5	91-162.5	20-62.5	

\* The first number in the chart indicates number of people using the site.

The second number indicates number of hours spent in the particular activity.

of paddlefishing is increasing greatly, and, as the fish population matures, the average fish weight is increasing (Martin personal communication). Next, recreational use within the study area would be considered relatively light if the number of recreationists per river mile could be found on a yearly basis. This, however, is due to limited access to large portions of the river. It has been shown that for various seasonal activities at various sites, recreational use is substantial.

No discussion or conclusions can be drawn as yet from the game warden creel census data.

#### ANTICIPATED ACTIVITIES FROM JULY 1 TO SEPTEMBER 30, 1975

The coming quarter will be used to evaluate recreational use and attitudes along sections of the Yellowstone River with a revised questionnaire.

In addition, aerial and automobile trips to each section will provide an outline of recreational visitation frequencies. To obtain these frequencies, each of the five sections will be visited once a week on random days, including weekends. Each visitation will also randomly occur at either 6:00 am to 2:00 pm or 2:00 pm to 10:00 pm.

A series of staff gages will also be used at each recreational site to 1) measure the water level, and 2) relate it to recreational use.

Since the coming quarter is the most popular time of year for outdoor activities, data gathering will be the major activity.

This task is approximately one-third completed.



TASK 8.    INVESTIGATION OF THE IMPACT OF ALTERED STREAM FLOWS ON CHANNEL PROCESSES AND DYNAMICS. The Grantee shall study stream channel processes and dynamics at various discharge rates to determine the effect of stream flow alterations on stream stage and channel stabilization. The Grantee shall provide hydrologic expertise for investigators engaged in other tasks set forth in this article.

## VIGIL NETWORK PROGRAM

### GENERAL INFORMATION

Supervised by Bob Curry and Mark Weber, UM Geology Department, vigil site personnel at the University of Montana are undertaking research in streams of the Yellowstone River Basin in conjunction with other tasks of the study. Individual vigil sites, which together comprise the vigil network, are locations where morphologic-environmental conditions are described in detail to enable (1) a qualitative or semi-quantitative evaluation of stream-channel dynamics and stability, and (2) an observational record of changes in these conditions through time, (3) projections of long-term fluvial morphologic changes resulting from changes in certain hydrologic parameters (e.g. discharge) of a given stream.

Data concerning vigil network sites will be recorded in a standardized file format (Enmett and Hadley 1968). In addition to its use in this project, information derived from the Yellowstone Vigil Network will be made available to national and international scientific communities through the repository managed in this country by the United States Geological Survey.

The vigil project on the Yellowstone and its tributaries will provide data on approximately 20 sites. These sites will cover the broadest possible spectrum of channel sizes (first or second order tributaries to mainstem Yellowstone River), and, in the smaller streams, the broadest possible spectrum of watershed perturbation, from severely disturbed to nearly undisturbed.

Particular information to be gathered at each vigil site includes detailed measurements of channel geometry through cross-sectioning and profiling, measurements of bed material sizes and distributions, surveys of riparian vegetation, and collection and preservation of benthic fauna for subsequent identification.

### COMPLETED ACTIVITIES

Activities completed to date can be summarized as follows: (1) location and review of literature pertinent to the study, (2) identification and acquisition of material necessary for the study, and (3) tentative location of specific vigil sites.

Tony VanderPoel has compiled a review of quaternary geomorphic studies in southeastern Montana. This report has been submitted to the Department of Natural Resources and Conservation.

A bibliography pertinent to the vigil site project has been compiled and transferred to cards for the general project file.

Necessary topographic base maps and aerial photographs have been acquired, and all field equipment has been identified and/or acquired.

Project personnel have formulated a standard methodology for benthic biota documentation at individual vigil sites, and material pertinent to identification of riparian vegetation species has been assembled.

Field work carried out in 1973 on several potential vigil sites has been reviewed. Eight of these locations were determined to be useful as vigil sites for this project:

1. Armells Creek--2 sites
2. Little Bighorn River--1 site
3. Rosebud Creek--2 sites
4. Sarpy Creek--1 site
5. Tullock Creek--2 sites

In addition, four potential sites on the Yellowstone and three potential sites on the Bighorn have been identified. Several low-order stream sites are also anticipated, but site selection must await the field season.

It is anticipated that the installation of vigil sites on higher order streams (Yellowstone and Bighorn) will require the aid of a boat and crew from DNRC. Alternately, some of the diversion cross sections already installed by DNRC have been considered as potential vigil sites. Their utility as vigil sites will be determined by on-site inspection. Additional surveying with boat and crew of those sites determined to be satisfactory vigil sites would be unnecessary.

## PLANNED ACTIVITIES

Activities planned for the summer field season can be summarized as follows:

1. Identification and location of vigil sites.
2. Vigil site installation.

Tom Bateridge will begin field work in the first week of July. During the first three weeks all vigil sites and potential vigil sites will be located and evaluated. Private landowners will be located and contacted for land access permission. DNRC diversion cross-section sites will also be visited and evaluated as vigil sites.

On or about July 20, Gary Parry will join the project. He and Bateridge will spend the duration of the field season installing new vigil sites and resurveying and sampling those established in 1973. It is anticipated that a total of about 20 vigil sites will be established or re-established for this project. It is hoped that field work will be completed by September 10, 1975.

## CHANNEL PROCESSES AND DYNAMICS

Roy Koch's progress to date on the channel morphology portion of the study has been primarily in problem identification and searching for a methodology for solution through review of current literature and discussion with UM personnel. The only direction provided for the study is a section in the proposal which states that we will "observe changes in erosion and sedimentation rates as a function of flow rate so that consequences of possible long term changes in historical flow patterns may be evaluated." Given this objective, the following flexible problem statement and solution methodology have been formulated.

### PROBLEM STATEMENT

Determination of the changes mentioned above will most certainly require the evaluation of the possible future alteration of cross-sectional channel geometry, i.e., width, depth, and corresponding changes in flow velocities, and in longitudinal stream profile characteristics such as length, sinuosity (if applicable) and slope. These alterations in stream morphology will be due to the development of large-scale diversions or impoundments or some combination of the two which will result in changes in flow-frequency characteristics and/or sediment-input characteristics in the basin. The study should be designed to evaluate these changes and predict the possible consequences on channel morphology.

### SOLUTION METHODOLOGY

The primary emphasis will be in the collection of relevant data on existing and past channel and river characteristics. These data will include:

- 1) Channel cross sections as determined from ongoing surveys and past data such as USGS gaging records,
- 2) Longitudinal characteristics such as length, sinuosity, and slope determined from aerial photos and maps,
- 3) Flow-frequency characteristics to be determined from published data by standard analysis,
- 4) Sediment and channel bed characteristics as determined from USGS data and past surveys, where available, and actual field data collection where practical.

From these data it is hoped that effects on channel geometry, stream profile, and total sediment load will be predictable. Emmett's (1972) work should give a starting direction in the correlation of channel geometry with flow and effects of changes in flow regime on the channel geometry. His work will have to be expanded, however, since we are introducing two additional variables: changing flow frequency and changing sediment characteristics. Changes in flow frequency should be relatively easily evaluated for each alternative future when the scenarios have been completed. This should simply be a matter of reducing the annual peak by the appropriate amount and reevaluating the flood-frequency relationship. The evaluation of changes in sediment characteristics will be somewhat more difficult, and a methodology for evaluating this change is still being sought.

Yang (1971) and Yang and Stall (1974) have presented some original work in the area of stream morphology and sedimentation which could prove valuable in this study. Using Horton-Strahler relationships (stream-length ratio, stream concavity, stream frequency) Yang has shown that a profile for a stream can be calculated for the condition of 'dynamic equilibrium' (i.e. present conditions) and the present condition if the Horton-Strahler relationships apply. Any deviation of one profile from the other should indicate some local constraint. This might be used in our study to evaluate the effects of diversions and impoundments on stream profiles. Yang has also developed a method of predicting total sediment concentration in natural rivers based on a concept called "unit stream power" which is defined as the time rate of potential energy expenditure per unit weight of water. Extensive data were used in establishing the unit stream power equation and it reflects the effects of variation of particle size, water depth, and water temperature on total sediment concentration. Investigations into the applicability of Yang's work in the Yellowstone Basin are continuing.

This task is approximately 35% completed.



TASK 9.    WATER MODEL CALIBRATION AND RIVER BASIN SIMULATION.    The Grantee shall calibrate the mathematical Montana water planning model to selected field impacts. The Grantee shall then conduct a series of computer runs to simulate the impacts of various degrees and configurations of water use.

George Cawlfieid, Satish Nayak, and Roy Koch, all of DNRC, are attempting to mathematically simulate the Yellowstone River Basin hydrology. Three models are involved: the State Water Planning Model, the U.S. Army Corps of Engineers Streamflow Synthesis and Reservoir Regulation (SSARR) model, and the U.S. Bureau of Reclamation HYD-2 model.

#### STATE WATER PLANNING MODEL

George Cawlfieid and, more recently, Satish Nayak have been calibrating this model, which has monthly and annual versions. The Yellowstone was disaggregated into eight subbasins, and data has been accumulated for each.

The annual and monthly versions of the model for the Tongue basin have been calibrated. Test simulations have been run for the annual version and are underway for the monthly version.

The assumptions made in the annual simulation for the Tongue are not based on an existing damsite, but rather a hypothetical situation for testing of the simulation version. The logic assumes a full reservoir with a capacity of 450,000 acre-feet and a minimum flow of 199,500 acre feet/yr. If inflow is inadequate to meet minimum flow requirements, water is released from storage. If inflow exceeds minimum flow requirements the excess goes to storage until the reservoir is full and then inflow is passed through as outflow.

Figure 19 is a graph showing reservoir storage and stream outflow in acre-feet for the 30-year period.

The Civil Engineering Department at MSU had a graduate student working on subbasin 42KJ (Yellowstone River mainstem from Bighorn to Miles City). Initial calibration of both the annual and monthly versions is complete. No simulations have been run.

Data preparation for the Powder and Bighorn rivers is nearly complete. Generation of diversion data is needed before monthly modeling of these basins can start. Annual modeling of these two basins has begun.

In addition to the above-mentioned basin efforts, certain types of data have been prepared for the entire Yellowstone Basin in Montana. Root-zone moisture-holding capacity data (a direct input to the model) and crop data (used to calculate potential evapotranspiration) are complete.

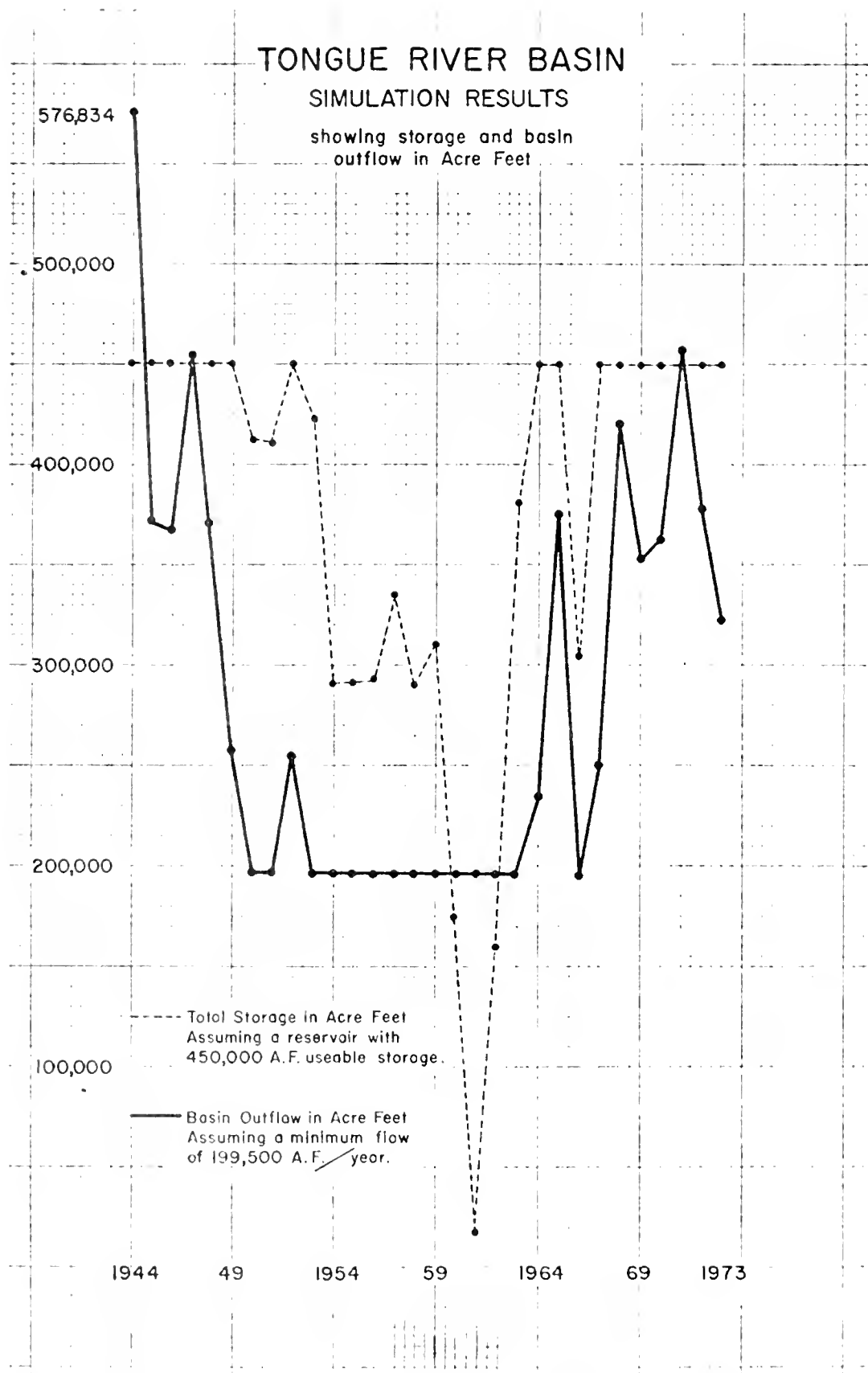


FIGURE 19. Simulation of Tongue River Basin with hypothetical storage and depletion.

Tables 55 and 56 show the status of the annual and monthly modeling efforts by subbasin.

Literature is being reviewed in search for optimization models which may be used in economic studies or evaluation of development alternatives (Hall and Dracup 1970, O'Laoghair and Himmelblau 1974, CRWR 1974, Texas Water Board 1972).

Data preparation and model calibration is approximately 25% complete.

### STREAMFLOW SYNTHESIS AND RESERVOIR REGULATION (SSARR)

SSARR is a digital computer program of the hydrologic cycle which, when calibrated, has the capability of simulating basin outflow on an hourly basis given precipitation, evaporation, and several trial and adjustment relationships of physical watershed characteristics. The calibration is accomplished through attempts to reconstitute known streamflows while varying the trial and adjustment parameters for the best simulation of the known data.

As a first attempt to use the model, the Rosebud Creek Watershed in South-eastern Montana was chosen and daily data were gathered. Rosebud Creek was chosen under the assumption that, since it is a relatively small watershed, development--and therefore unaccounted water use--would be minimal. This assumption proved false, and several attempts at simulation were fruitless, even when the data were expanded to hourly intervals. Given these results, it was decided that a larger basin, where diversion points were well defined, would be a better starting point for model calibration. After examining the Tongue and Bighorn Rivers, the Bighorn was chosen as the watershed to be used for further analysis.

Data collection for the Bighorn River was directed toward compiling hourly data, since these data could be consolidated to a larger time interval if hourly data were not deemed necessary but data gathered on a greater time frame could not be reduced. On this premise, data management programs were developed which accepts as input hourly data and produces as output, punched to the proper format for input to the SSARR, cards with data on the desired time intervals: 1, 3, 6, 12, or 24 hours. In the data collection process it became evident that even though the diversion points in the Bighorn River Basin were easily identified, the actual diversion rates were only available at the Bighorn Canal.

At this point in the process, approximately five months after the first attempts to calibrate and use the SSARR model, it was decided that progress was much too slow and many of the data availability problems, especially in defining diversion rates, were too great to warrant further use of the model, at least in the immediate future.

### HYD-2

After difficulties were encountered with the SSARR model, it was decided to investigate the U.S. Bureau of Reclamation HYD-2 model, used in the studies for the Northern Great Plains Resources Program. After a brief orientation and training session by Dave Haisten of the Bureau, this program was adopted in order to provide some quick results for input to the planning process. An analysis of the 1970 level

TABLE 55. Status of Task 9 state water model modeling effort for the monthly version

MONTHLY VERSION	42M &				
	Tongue	Bighorn	Powder	42L	43KJ
Data Collection/Preparation					
Temperature	C	N	N		C
Precipitation	C	C	C		C
Streamflows	C	C	C		C
Reservoir Storage	C	N	N		C
Root Zone Moisture Holding Capacity	C	C	N/A		C
Potential Evapotranspiration	C	C	C		C
Crop Acres (Irrigated, Nonirrigated, Native Vegetation, Phreatophytes)	C	C	C	C	C
Frost Data	C	C	C		C
Latitude	C	C	C		C
Calibration	C				C
Test Simulation	N				C
Real Simulations					
#1					
#2					
#3					

C = Complete  
N = Nearly Complete  
N/A = Not Applicable

TABLE 56. Status of Task 9 state water model modeling effort for the annual version

ANNUAL VERSION	42M & 42L				
	Tongue	Big Horn	Powder	42K	43KJ
Data Collection/Preparation					
Temperature	C	N	N		C
Precipitation	N/A	N/A	N/A	N/A	N/A
Streamflows	C	C	C	C	C
Reservoir Storage	C	C	C		C
Root Zone Moisture Holding Capacity			N/A	N/A	N/A
Potential Evapotranspiration	N/A	N/A	N/A	N/A	N/A
Crop Acres (Irrigated, Nonirrigated, Native Vegetation, Phreatophytes)	N/A	N/A	N/A	N/A	N/A
Frost data	N/A	N/A	N/A	N/A	N/A
Latitude	N/A	N/A	N/A	N/A	N/A
Calibration	C			C	C
Test Simulation	C				
Real Simulations					
#1					
#2					
#3					

C = Complete  
N = Nearly Complete  
N/A= Not Applicable

runoff data used by the Bureau showed their methods to be sound, and these data were adopted, unaltered, for use with HYD-2. The program is now operational and water supply studies have been started. In the near future, these studies will take the following form:

1. Determine how often the Montana Department of Fish and Game instream flow reservation requests have been met historically in the basin.
2. Determine how Yellowtail Dam could be operated for maximum irrigation water supply and the amount of water available above instream flow reservations.
3. Determine how much water can be made available from Yellowtail without honoring instream flow reservations.
4. Determine how much water can be made available from Yellowtail for irrigation honoring varying levels of instream flows.
5. Assuming a minimum streamflow, determine how much water is available for irrigation.

Along with these water supply schemes, the availability of water for energy development under the various scenarios will also be analyzed, along with different combinations of energy and irrigation development as they relate to the instream flows.

Overall, this task is about 30% completed.

TASK 10. COMMENCEMENT OF FINAL IMPACT EVALUATION OF WATER WITHDRAWALS AND WATER DEVELOPMENT ON THE MIDDLE AND LOWER PORTIONS OF THE YELLOWSTONE RIVER DRAINAGE, MONTANA. The Grantee shall commence an analysis in three stages:

- A) Determine the mixes of coal-based water consumption to be evaluated in future years.
- B) Project the demands that other water users will impose in future years.
- C) Analyze the field impacts of the foregoing competing demands.

Phase (A) of this Task has been discussed under Task 5; phase (B) is included in Tasks 4 and 5; phase (C) is an integral part of Tasks 1-9.





TASK 11. COMMENCEMENT OF ECONOMIC EVALUATION OF WATER WITHDRAWALS AND WATER DEVELOPMENT ON THE MIDDLE AND LOWER PORTIONS OF THE YELLOWSTONE RIVER DRAINAGE, MONTANA. The Grantee shall commence an economic evaluation of the impacts and assessments set forth in the foregoing tasks. The Grantee shall provide such coordination of the foregoing tasks as is necessary to make this economic evaluation.

A major subobjective of this study is to quantify economic values and costs of impacts identified in the earlier tasks, with attention to conflicts and trade-offs. Begun in January, 1975, by Elna Tannehill of DNRC, initial areas of concentration under this task have been to determine a consistent approach to evaluation of various water uses and to be sure other task leaders were gathering the information necessary to the analysis.

The approach chosen is that used by the National Water Commission (1973):

"The objective is to obtain values for water that are comparable to the price-based values that allocate other resources and products throughout the economy. The principle is to estimate value on the amount a user would be willing to pay for the water. His willingness to pay for the water reflects the desirability, usefulness, and importance of water to him."

The social costs of certain uses may be higher than the price a particular class of users is willing to pay, as when government policies provide a subsidy to the capital needs of a program that is not entirely repaid by the direct beneficiary. These uses will be analyzed with and without existing subsidies to make output comparable to unaided uses. Social and environmental factors not reflected directly in market values will be treated qualitatively.

The National Water Commission contracted many detailed studies in connection with production of its final report to the president. Two of these (Young and Gray 1972 and Butcher et al. 1972) have been and will continue to be of great value to this portion of the analysis.

The second emphasis in this phase of economic analysis has been coordination with task leaders to insure an adequate data base.

The tasks being carried out by the Department of Fish and Game (1, 2, 3, 7) will be combined. The recreation survey being used in Task 7 contains several questions whose purpose is to ascertain economic characteristics of recreation users. It should be possible to show how many dollars worth of recreational opportunity would be lost permanently by large changes in the river level. Most studies of water value for recreation have dealt with reservoirs; if the data and analysis of this portion of the study live up to expectations, a contribution to the body of knowledge of recreation valuation will have been made.

The value of water for irrigation has been studied under many circumstances. The relationship between costs irrigated farms incur and the prices they must receive for products to make irrigation worthwhile is being addressed in Task 4. A dollar value for water in irrigation use can be derived by comparing dryland costs and returns to irrigated costs and returns. Irrigation system installation costs, as well as operating cost, will be considered through the program developed by DNRC.

Water quality is an economic problem since changes in water quality from one use to another require more or less treatment to allow downstream uses to take place. The value of the uses foregone downstream, if any, is the measure of the cost of water pollution to society, but "the most appropriate method for determining the value of water in industrial uses is to examine the cost of alternative processes that will produce the same product value using less water" (National Water Commission 1973). A study (Townsend and VanLanen 1974) has recently compared costs of dry and wet cooling towers in thermal-electric generating plants that will provide information for this portion of the analysis. If Yellowstone water is not degraded by municipal and industrial use enough to preclude necessary downstream uses, then the economic costs will be insignificant.

It is as water becomes an economic good (scarce) that it needs to be valued in dollars; since water may be allocated to one set of uses rather than another, evaluation of tradeoffs is necessary. The dollar, then, is a common measure of opportunity costs incurred by a decision to use water one way rather than another. The "Downstream" model developed by the United States Forest Service may be used to balance dollar values with any variety of constraints.

This task is estimated to be 30% completed.

TASK 12. EVALUATION OF WATER MODEL. The Grantee shall provide an evaluation of the utility of the water modeling method used pursuant to this grant, with attention to its potential utility as a prototype in the Old West region of Montana, Wyoming, North Dakota, South Dakota, and Nebraska.

No work has been done on this task and none is anticipated until Task 9 is further along.



FINANCIAL INFORMATION

Thru June 30, 1975

	<u>Quarter</u>	<u>Total</u>
Salaries	27,706.13	59,144.20
Benefits (Actual)	<u>3,040.01</u>	<u>6,812.58</u>
Total Personal Services	30,746.14	65,956.78
Contracted Services*	37,599.45	59,977.40
Supplies & Materials	288.60	3,650.92
Communications	63.81	1,142.15
Travel	3,446.33	7,329.64
Rent	234.00	1,273.10
Repair & Maintenance	109.10	128.45
Other Expenses	<u>411.73</u>	<u>1,186.72</u>
Total Operating Costs	42,153.02	74,688.38
TOTAL EXPENDITURES	12,899.16	140,645.16
INDIRECT COSTS (5.77%)	<u>4,206.29</u>	<u>8,115.23</u>
TOTAL COSTS TO DATE	77,105.45	148,760.39

\* See Attachment #1

FUNDS ON HAND JUNE 30, 1975	(294.39)
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ESTIMATED FUNDS NEEDED FOR QUARTER ENDING SEPTEMBER 30, 1975	60,000.00
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## ATTACHMENT #1

## DETAIL OF CONTRACT PAYMENTS

Thru June 30, 1975

	<u>Quarter</u>	<u>Total</u>
Dept. of Health:		
Personal Services	14,606.63	22,868.63
Supplies & Materials	2,788.11	2,904.21
Travel	951.22	1,926.79
Other Expenses	<u>14.40</u>	<u>14.40</u>
Total	18,360.36	27,714.03
Dept. of Fish & Game:		
Personal Services	12,488.72	19,418.71
Contracted Services	29.75	29.75
Supplies & Materials	467.46	716.86
Communications	61.47	73.77
Travel	1,442.50	3,520.20
Aircraft Rental	1,876.16	3,420.16
Utilities	4.80	4.80
Repairs & Maintenance	230.32	235.22
Other Expenses	<u>1.60</u>	<u>1.60</u>
Total	16,602.78	27,421.07
University of Montana:		
Personal Services	-0-	1,049.98
Supplies & Materials	<u>-0-</u>	<u>18.13</u>
Total	-0-	1,068.11
Satish Nayak, Computer Systems Analyst	1,944.90	1,944.90

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